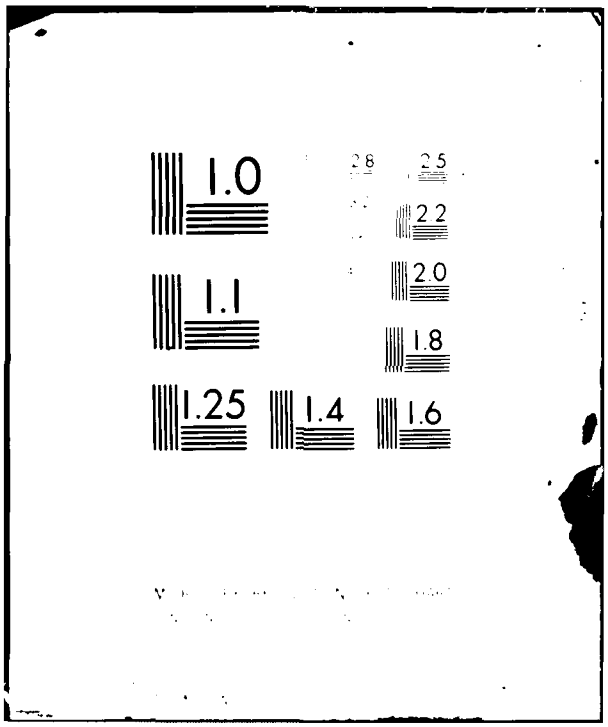
AD-A115 985 ILLINOIS NATURAL HISTORY SURVEY HAVANA RIVER RESEARCH LAB F/G 6/6
FISH AND WILDLIFE HABITAT CHANGES RESULTING FROM CONSTRUCTION O--ETC(U)
APR 79 R E SPARKS, F C BELLROSE, F L PAVEGLIO

UNCLASSIFIED NL

1 OF 3
AD A
115 985



1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

FISH AND WILDLIFE HABITAT CHANGES RESULTING FROM CONSTRUCTION OF A NINE-FOOT CHANNEL ON POOLS 24, 25, AND 26 OF THE MISSISSIPPI RIVER AND THE LOWER ILLINOIS RIVER

by
Richard E. Sparks, Ph.D., Aquatic Specialist
Frank C. Bellrose, D.Sc., Wildlife Specialist
F.L. Paveglio, Jr., M.S., Wildlife Assistant
M.J. Sandusky, M.S., Aquatic Assistant
D.W. Steffeck, M.S., Wildlife Assistant
C.M. Thompson, B.S., Aquatic Assistant

Illinois Natural History Survey
River Research Laboratory
Havana, Illinois 62644

Prepared for U.S. Army Engineer District, St. Louis
Under Purchase Order Numbers LMSSD 77-2897 and 77-2942

April 1979

AD A115985

DTIC FILE COPY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A115 985	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Fish and Wildlife Habitat Changes Resulting From Construction of a Nine-Foot Channel on Pools 24, 25, and 26 of the Mississippi River and the Lower Illinois River		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard E. Sparks, Franck C. Bellrose, F. L. Paveglio, M. J. Sandusky D. W. Steffeck, C. M. Thompson		8. CONTRACT OR GRANT NUMBER(s) LMSSD77-2897 and LMSSD 77-2942
9. PERFORMING ORGANIZATION NAME AND ADDRESS Illinois Natural History Survey, River Research Laboratory Havana, IL 62644		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis 210 Tucker Blvd., North St. Louis, MO 63101		12. REPORT DATE April 1979
		13. NUMBER OF PAGES 225
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this report it to compare the fish and wildlife habitat in Pools 24 and 25 of the Mississippi River and Pool 26 of the Mississippi and Lower Illinois Rivers from before to after construction of the navigation dams.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

DTIC
COPY
INSPECTED

LIST OF TABLES

LIST OF FIGURES

PART I: INTRODUCTION

The purpose of this report is to compare the fish and wildlife habitat in Pools 24 and 25 of the Mississippi River and Pool 26 of the Mississippi and lower Illinois Rivers from before to after construction of the navigation dams. The dates of construction and first operation are given below (U.S. Army Engineer District, St. Louis, 1975: 4-13):

Lock and Dam Number	Construction Initiated	Operational	Normal Pool Level Reached
24	20 July 1936	12 March 1940	14 May 1940
25	12 November 1935	18 May 1939	11 July 1939
26	13 January 1934	1 May 1938	8 August 1938

The study reach of the Mississippi River extends from Alton, Illinois upstream for 98.3 miles to near Saverton, Missouri (Figures 1 and 2). Charts of the upper Mississippi River have been prepared by the U.S. Army Engineer Division, North Central, Chicago, Illinois (1975) and locations are given in river miles, starting from mile 0.0 at the intersection of the Ohio and Mississippi Rivers near Cairo, Illinois and proceeding upstream to a point just above Minneapolis-St. Paul, Minnesota. The study area of the Mississippi River used in this report extends from Mississippi River mile 202.9 to 301.2. The navigational locks and dams along the river impound waters, called pools, which provide convenient reference to the geographic location of various sections of the study area (see Figures 1 and 2).

The lower part of the Illinois is influenced by Dam 26 on the Mississippi. Charts of the Illinois Waterway have been prepared by the U.S. Army Engineer District, Chicago (1974) and locations are likewise given in river miles, starting from mile 0.0 at the confluence of the Illinois and Mississippi Rivers, at Grafton, Illinois, and proceeding upstream to Chicago. The study reach of the Illinois River extends from mile 0.0 upstream to the LaGrange Lock and Dam at mile 80.3. Along both

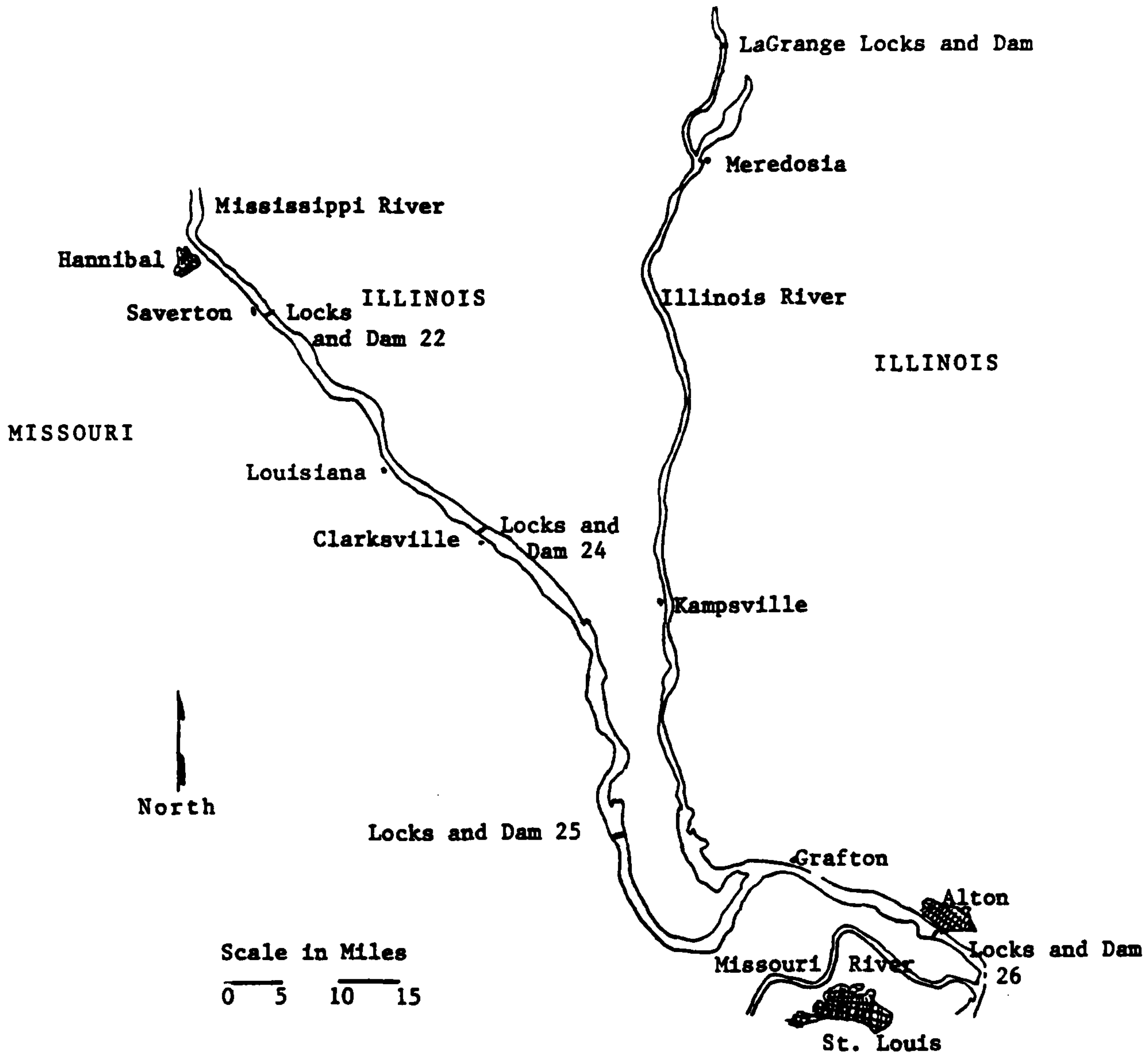


Figure 1. Map of the study area, showing the locks, dams, towns, and cities.

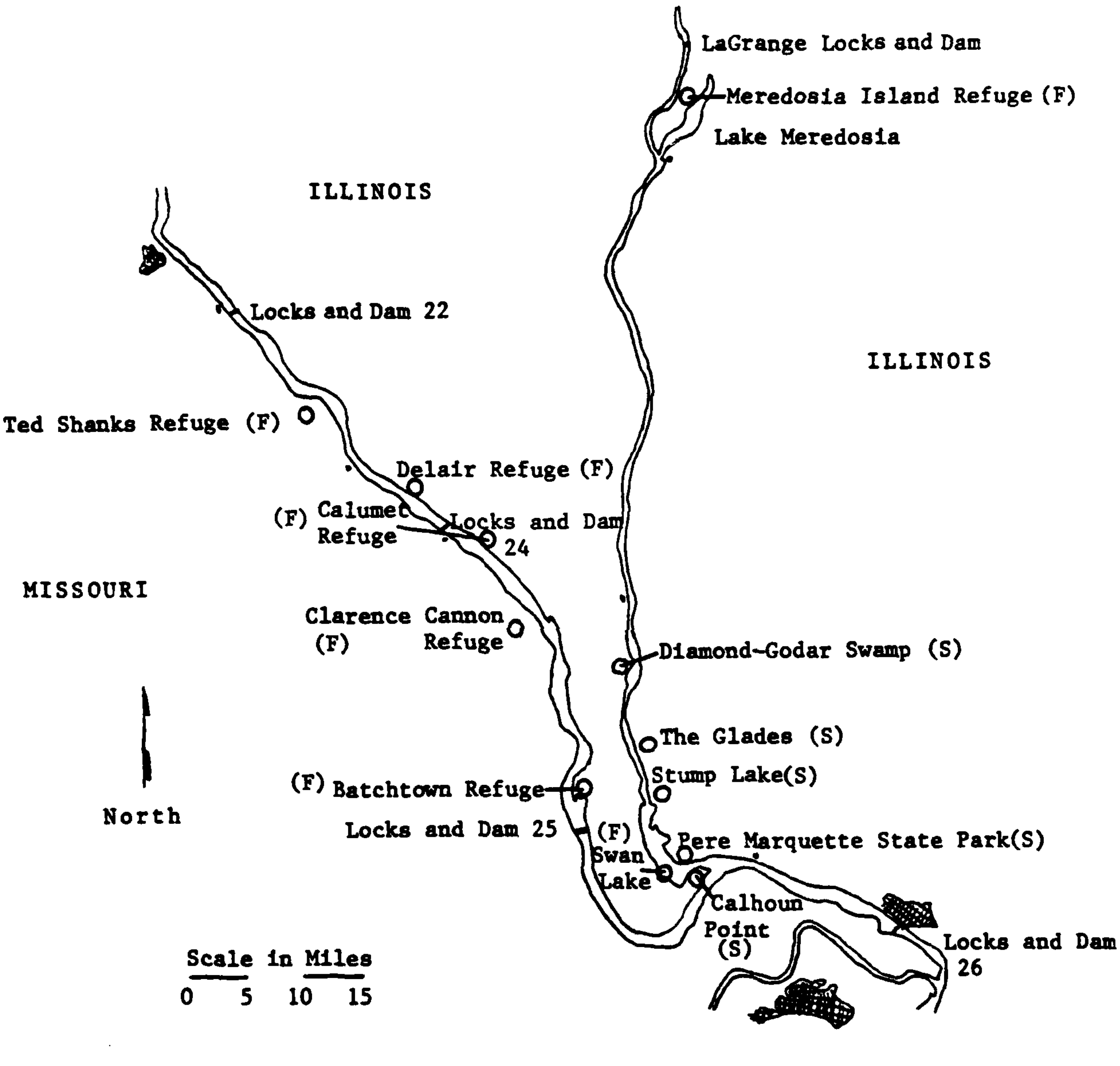


Figure 2. Map of the study area showing the bottomland lakes, wildlife refuges, and state parks.
(F) = Federal refuge.
(S) = State refuge.

rivers, mileages are often given on navigation aids, such as buoys, markers, and lights.

Both rivers have been subject to a variety of influences besides the construction of the locks and dams associated with the 9-foot navigation channel. For example, the navigational improvements associated with the 4½-foot channel and the 6-foot channel on the Mississippi River caused some long-term changes in the morphometry and hydrology of the river (U.S. Army Engineer District, St. Louis, 1975: 2-3). Both rivers were subjected to increasing sediment loads as agriculture intensified in the drainage basin, and to increasing pollution loads as population centers increased. Virtually the entire Illinois River was affected following the 1900 diversion of sewage effluent from Chicago into the upper reaches of the river. Draining and leveeing of the floodplain has markedly reduced the amount of natural habitat. Insofar as possible, we have tried to sort out the effects attributable to the nine-foot navigation project from the other effects, but many of our conclusions are necessarily of a qualitative, rather than a quantitative nature. Another handicap was that maps and tables showing the acreage of wetland and aquatic habitat existing before and after construction of the navigation dams did not become available until after our report was completed.

PART II: MATERIALS AND METHODS

Aquatic Communities and Water Quality

We conducted a literature search to find published information on aquatic communities and water quality in the study area before and after the dams were constructed. Unpublished results of biological surveys on the Illinois River were available in the files of the River Research Laboratory at Havana. Some recent unpublished information on water quality, benthos, and plankton in Meredosia Lake was obtained from the Water Quality Section of the Illinois State Water Survey at Peoria. A pre-publication version of a compendium on the fisheries of the upper Mississippi River was supplied by Mr. Jerry Rasmussen, coordinator, Upper Mississippi River Conservation Committee. We also contacted fishery biologists in the Illinois and Missouri Conservation Departments. Mr. Larry Dunham, special projects staff biologist, Fisheries Division of the Illinois Department of Conservation, graciously supplied recent statistics on the commercial fishery and a copy of a Ph.D. dissertation, "The Development and Current Status of the Upper Mississippi River Commercial Fishery" (Sullivan, 1971).

In order to identify the immediate and direct effects of construction of the navigation dams, we tried to find water quality and biological surveys which had been done just prior to, and just after the dams were constructed. In some cases, the only available pre- and post-impoundment data were widely separated in time. We used these data, if the sampling methods were comparable, and tried to distinguish changes attributable to navigation from changes attributable to other factors, such as pollution. If information was not available on the study area, we tried to find information on comparable areas outside the study area.

Finally, we looked at not only information obtained just after completion of the dams, but all readily available information collected since that time, in order to assess any long-term or indirect impacts of the nine-foot navigation project, such as those effects which might be associated with barge traffic.

Sedimentation

In order to determine the rate of sedimentation and fill of Lake Meredosia located on Pool 26 of the Illinois River (river miles 72-78), six depth transects were taken. Depths were taken through the ice at approximately 200-foot intervals with an aluminum pole fitted with a 4.5-inch diameter aluminum foot. The depths were correlated with the Illinois River gauge at Meredosia to determine mean sea level elevations.

The sedimentation and fill rates were calculated by comparing our depths with those recorded in 1903 by W.J. Woerman, U.S. Army Corps of Engineers, and depths recorded by the Illinois Division of Waterways in 1956. The water depths from the Woerman maps were converted from Memphis Datum to MSL (1929 general adjustment) by subtracting the conversion factor of 7.345.

Terrestrial Communities

Wetland Plants

Aquatic and moist soil plant acreages were obtained by planimetering vegetation maps. These maps had been drawn using inspection and rough triangulation by Frank Bellrose from 1941 through 1944. Species were listed according to taxonomic order from Gray's New Manual of Botany (1908). Changes in vegetation from 1946-1976 were procured from annual narrative reports of the area managers for the Mark Twain National Wildlife Refuge. A recent study of vegetation (Klein *et al*., 1975) in the study area was reviewed.

Population Data

The population data for waterfowl, cormorants, and bald eagles were obtained from the 1956-1977 fall waterfowl censuses made by the Illinois Natural History Survey. Waterfowl use was expressed as duck days. This was calculated by totaling the weekly censuses from October 1 through December 1 and multiplying by seven. Each duck-day represents one duck spending one day in the study area. Bird population data for the

Meredosia, Batchtown, and Calhoun divisions of Mark Twain National Wildlife Refuge from October 1975 to October 1976 were taken from Wildlife Information Reports. Great blue heron and common egret nest counts were taken from unpublished data obtained from R.R. Graber, J.W. Graber, and data collected by Frank Bellrose.

Information on the number of deer killed during the 1974, 1975, and 1976 hunting seasons was acquired from Forrest Loomis, forest game biologist for the Illinois Department of Conservation. The deer kill information from Missouri was obtained from Wayne Porath, deer biologist, Missouri Department of Conservation. Furbearer harvest figures for Missouri were procured from Dave Erickson, small game biologist, Missouri Department of Conservation. Narrative reports for the Calhoun and Batchtown units of the Mark Twain National Wildlife Refuge were obtained from the refuge manager, George Payton, and the Quincy headquarters.

PART III: RESULTS AND DISCUSSION

Aquatic Communities

Plankton — Mississippi River

We were not able to find any surveys of the plankton in the study reach of the Mississippi prior to 1930. Consequently, we have no way of comparing plankton populations before and after construction of the navigation dams. We can hypothesize that the navigation dams, by making portions of the Mississippi River more lake-like, may have increased the population of truly planktonic forms which live in the water column, as opposed to forms which live attached to the substrate and appear in the water column as the result of scouring.

An excellent survey of phytoplankton and zooplankton in the study reach was conducted in 1974 by Colbert *et al.* (1975), and they also provide a review of other recent plankton studies. Colbert *et al.* (1975: Table 2) took plankton samples from both main channel and side channel habitats at 13 locations in the Mississippi between river miles 201.3 and 302.2. Samples were taken at the beginning of July, 1974 during a period when water levels were declining from flood stage and again in mid-September, after water levels had been stable at approximately the 31-year average level since the end of July (Colbert *et al.*, 1975: Figure 3).

They found that the density of phytoplankton in the main channel increased more than 100 times between July and September, although nutrients (nitrogen and phosphorus) were higher in July (Colbert *et al.*, 1975: 51, 53). The increase in phytoplankton during the period of stable water levels was attributed to decreases in: (1) turbidity, (2) current velocity, (3) mechanical destruction of algae, and (4) dilution of algal populations by direct rainfall and surface and groundwater runoff (Colbert *et al.*, 1975: 48, 51).

An isolated bloom of green algae (primarily *Tetraedron minimum*) occurred at river mile 215.5 in September. The density of green algae

exceeded 521,000/l at this station, located just below the Illinois River confluence, but *T. minimum* occurred at a density of only 123/l at a side channel station immediately upstream at Mississippi River mile 220.7, and no *T. minimum* occurred in samples below river mile 215.1 on the Mississippi, or at Illinois River mile 23.1, just upstream from the confluence (Colbert *et al.*, 1975: 51).

Colbert *et al.* (1975: 54) concluded that the side channels played a major role in the productivity of the Mississippi River:

> 119. It is apparent that side channels are a very important habitat in the Upper Mississippi River, particularly during high-flow periods. They provide refuge in the form of slower moving waters, which leads to increased plankton abundance, which in turn provides a food source for phytoplankton feeders such as zooplankton, certain benthic insects, and particularly planktivorus fishes such as paddlefish, shad, and larval fishes. . . .
>
> 120. During reduced river stages, the impounded river channel becomes increasingly important as abundance of phytoplankton increases due to larger areas of slack water and associated reduced turbidity. Some side channels (river mile 201.3) have less input to the river proper since they actually become cut off from the river during low stages.

Colbert *et al.* (1975: 66) reached the following conclusions regarding zooplankton:

> Based on statistical analyses . . . , it was determined that total zooplankton density, zooplankton species diversity, and concentrations of Cladocera, Copepods, and Rotifera increased significantly between July (high flow) and September (low flow). Evenness index showed the reverse trend in that it decreased significantly between July and September. Statistical treatment of data combined for both sampling periods indicated that only the rotifers were significantly greater in side channel habitats.

Colbert *et al.* (1975: 61) indicated that the difference in flow regimes prior to the July and September sampling was the main reason for the marked difference in zooplankton populations in the main channel:

> 138. Mean total density for the main channel stations was 2.5/l during July compared to a total of 28.0/l during September . . . . This corresponds to the same trend observed for phytoplankton among main channel stations. The obvious overriding factor limiting zooplankton is flow rate. Zooplankton collected during high flow were from populations carried downstream from calm backwater areas, where reproduction could occur, and were greatly diluted in numbers by the rapid current created by surface runoff. The most abundant group found in the highly turbid waters characteristic of the July sampling period were the Copepoda, and they were present at a mean density of only 1.5/l.
>
> 139. The September sampling period followed a 49-day period of average river stage at Alton, Illinois . . . and the main channel was more lake-like due to closing of navigation dams. The observed density increase during this period was related to an increase in density of all three phyla, particularly Rotifera, which increased more than 20 times the density observed for this group in July . . . .
>
> 140. Mean number of taxa increased by a factor of four between sampling periods . . . . This increase is attributed to improved habitat conditions brought about by decreased flow and turbidity and increased phytoplankton abundance.

Zooplankton diversity and density also increased in side channel habitats between July and September, due to a reduction in flow during August and September (Colbert *et al.*, 1975: 65).

Phytoplankton -- Illinois River

Between June 12, 1894 and March 28, 1899 Dr. Charles A. Kofoid took 235 samples of plankton from the main channel of the Illinois River near Havana, at mile 128.5 (Kofoid, 1903: 291-340; Kofoid, 1904: 314-340), and in 1899 made one survey which included the lower 80 miles of the Illinois (Kofoid, 1903: 273-283). Biologists from WAPORA (WAPORA, 1974) took plankton samples from the Illinois River at Meredosia in September, 1973. The only post-dam *survey* of the plankton in the study reach of the Illinois River we have been able to locate was conducted by Colbert *et al.* (1975) in 1974. Although the two surveys were separated by a span of seventy-five years, the sampling methods used were strikingly similar, and the results are probably comparable, for the reasons given below.

We used Kofoid's data for the year 1898 (Kofoid, 1904: 314-340) for comparison with the 1974 data of Colbert *et al.* (1975: E29-E36).

Kofoid took plankton samples at one-week intervals throughout the year in 1898, and the hydrograph for that year was "normal" (Kofoid, 1904: 18). We used only the samples Kofoid had taken in September in the main channel, under stable low-flow conditions. The September samples of Colbert et al. were likewise taken under stable, low-flow conditions. Although Kofoid's samples were taken upstream from the study area, he conducted four studies (Kofoid, 1903: 273-283) of the longitudinal distribution of plankton in the river (one study included the lower 80 miles of the Illinois) and concluded that the plankton in the main channel was remarkably uniform. Hence, Kofoid's samples from the Havana area are probably generally representative of the main channel in both the middle and lower reaches of the Illinois River.

Kofoid used a pump to take an integrated vertical sample of water from the main channel. He pumped 250 liters of water through a plankton net made of Number 20 silk bolting-cloth. Colbert et al. (1975: 25) also took an integrated sample, consisting of 30 liters of water collected from the surface, mid-depth, and bottom of the water column, with a three-liter Van Dorn bottle. The water was poured through a Number 20 plankton net. Kofoid also used paper filters to collect the small plankton that passed through the Number 20 net. The number of organisms per liter trapped on the filter paper was sometimes 3 to 4 orders of magnitude greater than the number trapped in the plankton net (Kofoid, 1904: 314-340). Fortunately, Kofoid separated the counts obtained with the filter paper from the counts obtained with the net (Kofoid, 1904: Table I, 314-340), so the results reported in our Table 1 and Table 2 for the years 1898 and 1974 were both obtained using Number 20 plankton nets.

Although Table 1 shows that the number of species of phytoplankton apparently increased from 28 in 1898 to 68 in 1974, the increase is attributable to advances in the taxonomy of algae, rather than to a real change in the population. Kofoid (1904: 11-12) was well aware of the taxonomic uncertainties and limitations existing in the 1890's, and indicated that he probably underestimated the actual number of

species present:

> During the progress of this work, which was begun in 1894, every effort was made to secure all pertinent literature bearing on the genera of plants and animals represented in the plankton, and so far as possible in the enumeration of the collections the individuals were referred to "species" already described, or, in default of this, recorded as "unidentified." In some groups — notably the desmids, diatoms, and unicellular algae -- it was not possible under the conditions of plankton enumeration to apply to all the individuals enumerated the fine distinctions which specialists in these groups have made. . . . the difficulty lies not so much in finding representatives of these closely related species, but, rather, in drawing the lines between them and placing every individual enumerated in the proper pigeon-hole. To avoid this difficulty, the separation was not attempted in every case.

In Table 1, the increase in the number of species of diatoms (*Bacillariophyta*) in particular from four species in 1898 to 40 species in 1974 has more to do with the publication of *The Diatoms of the United States* (Patrick and Reimer, 1966) than with a real change in the phytoplankton.

The number of algae per liter, taken in Number 20 plankton nets, apparently did decline dramatically from an average of 176,887 in 1898 to 3,230 in 1974 (Table 1). The number of diatoms (*Bacillariophyta*) remained about the same, while the green algae (*Chlorophyta*) declined by a factor of 10 and the blue-green algae (*Cyanophyta*) declined by a factor of 1,000. Note that the results obtained by Colbert et al. at mile 2.5 (1975: E-28) were excluded from Table 1 because the number of organisms and number of species were much lower than at their other six sampling stations. The reduction in current velocity associated with the construction of the dam at Alton should have favored the green and blue-green algae. However, the potentially beneficial effects of the dam on phytoplankton have apparently been overridden by the increasing turbidity of the river (Mills et al., 1966: 7). Turbidity reduces light penetration, thus depressing photosynthesis by algae, and the suspended sediment may physically abrade algae.

Table 1

Comparison of Phytoplankton Populations in the Main Channel of the Illinois River in 1898 and 1974, Under Stable Low-flow Conditions in September[a]

Major Taxonomic Divisions	Number of Species		Number of Individuals Per Liter	
	1898[b]	1974[c]	1898[d]	1974[e]
Chlorophyta (desmids, green algae)	9	19	6,907	550
Bacillariophyta (diatoms)	4	40	2,544	2,455
Chrysophyta (yellow-brown algae)	2	-	2	-
Cyanophyta (blue-green algae)	3	3	167,400	166
Euglenophyta (euglenoid algae)	8	6	32	59
Pyrrophyta (dinoflagellates)	2	-	2	-
Total	28	68	176,887	3,230

[a]Data were obtained from Kofoid, 1904: 314-340, and Colbert et al., 1975: E29-E36. Although Kofoid's samples were taken upstream from the study area, he conducted four studies (Kofoid, 1903: 273-283) of the longitudinal distribution of plankton in the river (one study included the lower 80 miles of the Illinois) and concluded that the plankton in the main channel was remarkably uniform. Hence, Kofoid's samples from the Havana area are probably generally representative of the main channel in the fall of 1898. Both Kofoid and Colbert et al. (1975) used no. 20 plankton nets. Kofoid also collected plankton on filter paper, but these results are excluded from the table because Colbert et al. did not use micro-filtration.

[b]The total number of species taken on Sept. 6, 13, 20, and 27, 1898 at one sampling station in the Illinois River near Havana (mile 128.5).

[c]The total number of species taken at six sampling stations (miles 23.1, 45.6, 57.6, 58.3, 77.0, and 81.0) in the lower Illinois River. The station at mile 2.5 was excluded because the number of species was much lower than at the other six stations.

[d]The total number of individuals taken in the four collections in September, 1898, was divided by four to obrain an average density.

[e]The total number of individuals taken at six locations (excluding the atypical results from river mile 2.5) was divided by six to obtain an average density.

Another comparison of Kofoid's 1898 data with a more recent survey shows a decline in blue-green algae, but not in green algae or in total number of algae. WAPORA (1974: 11-12) took 14 10-liter samples of water during low-flow conditions on September 13 and 21, 1973 at Meredosia (river mile 71). The water was passed through a ten-micron mesh nanoplankton net, which would trap small plankton. The results may approximate those Kofoid obtained by using filter paper. The WAPORA biologists took all of their samples from the surface. If the water column were uniformly mixed, the samples would be comparable to those taken by Kofoid. However, if more plankton occurred on the surface than in deeper water, the WAPORA method would overestimate the abundance of plankton in the water column.

	Number Per Liter	
	1898[a]	1973[b]
Chlorophyta (green algae)	43,877	75,430
Bacillariophyta (diatoms)	153,811	252,214
Cyanophyta (blue-green algae)	167,605	2,140
Others	18,544	30,930
Total	383,837	360,714

[a]Kofoid, 1904: 314-340. Includes filter paper collections.

[b]WAPORA, 1974: D53-D54. Average of 14 samples taken Sept. 13 and 21, 1973.

The above table shows that when small algae are included in the plankton collections, the total number of algae has not shown a decline between 1898 and 1973. However, there apparently has been a marked decline in blue-green algae (Table 1 shows the same trend for large blue-green algae), which has been compensated for by increases in other groups, most notably in diatoms. Many phycologists believe diatoms are more tolerant of reduced light penetration and increased abrasion associated with suspended sediment than other types of algae (Colbert et al., 1975: 59). Some species of blue-green algae are considered nuisances when they grow to bloom proportions in nutrient-rich waters. The reasons for the marked decline in blue-green algae in the lower Illinois River are unknown.

Williams (1964: 813, 815) reported peak numbers of diatoms in the Illinois River at Grafton were 1,600,000 to 3,199,000 per liter in 1961-62, and at Peoria were 6,400,000 to 12,799,000 per liter in 1960-61 and 3,200,000 to 6,399,000 per liter in 1961-62. Williams' (1964: 811) collecting techniques captured all cells 4 microns or larger. His numbers are considerably higher than those obtained by other investigators, who used collecting techniques which would retain only larger diatoms and other types of algae. For example, WAPORA (1974: 11) used 10-micron mesh nanoplankton nets and Colbert et al. (1975: 25) used No. 20, 81-micron mesh plankton nets. Although Starrett (1972: 152) compared Williams' 1960-62 data at Peoria to unpublished data collected in 1964, 1969, and 1970, it is not certain that the sampling methods were the same. The unpublished counts (numbers per liter) reported by Starrett (1972: 152) were: 7,000,000 to 233,000,000 in 1964; 6,800,000 to 108,000,000 in 1969; and 8,500,000 to 117,000,000 in 1970. Starrett (1972: 152) reported that the decline in phytoplankton in the mid-1960's was associated with a sharp decrease in the abundance of blue-greens, while diatoms remained the dominant group. He suggested that the phytoplankton of the entire river might be limited by turbidity and the synergistic effects of toxic metals. Williams (1964: 819) attributed the high phytoplankton counts in the Illinois River to nutrient enrichment and high calcium hardness.

We do not feel that the reduction in algal populations is attributable to toxicity, because diatoms are as sensitive as, or even more sensitive than, other groups of algae. For example, Wong et al. (1978: 479) found that a diatom was more sensitive to metal toxicity than blue-green and green algae. Colbert et al. (1975: 59-60) found few statistical differences between phytoplankton populations in the lower Illinois and Mississippi rivers. Blue-green algae were approximately five times more abundant in the Mississippi than in the lower Illinois, and phytoplankton evenness was slightly higher in the Illinois. The causes of these differences are uncertain, and the physical-chemical data reported by Colbert et al. (1975) for the two rivers do not show any marked differences in phytoplankton. Colbert et al. (1975: 37-38)

observed significantly hgiher values for surface dissolved oxygen, turbidity, and pH in the Mississippi, while mean total alkalinity was higher in the Illinois. Mean total alkalinity in bottom water was likewise higher in the Illinois, while bottom temperatures were higher in the Mississippi. Of the 17 water quality factors (including nutrients and toxic substances) measured in the surface and bottom waters of the Illinois and Mississippi rivers by Colbert et al. (1975: 43) only total phosphorus differed significantly between the two rivers, being greater in the Illinois River. Since phosphorus can stimulate blooms of blue-green algae, one might expect more blue-greens in the Illinois than in the Mississippi, whereas just the reverse was true.

Significant differences between the two rivers in sediment concentrations of nutrients, metals, and toxic substances were noted by Colbert et al. (1975: 46-47). Sediment in the Illinois River contained more total phosphorus, iron, and ammonia than the Mississippi. Sediment in the main channel of the Illinois contained detectable pesticide concentrations whereas none were detected in the main channel of the Mississippi. PCB concentrations in sediment of the main channel of the Illinois were greater than in the Mississippi.

The phytoplankton populations in the lakes along the lower Illinois River are probably much higher than in the river, due to the lack of current and perhaps to some reduction in turbidity. Butts (unpublished report, 1975: Table 3) found the average density of phytoplankton in Meredosia Lake on August 7-8, 1975, was 1.7 million per liter and that diatoms and euglenoid algae dominated in different parts of the lake.

Zooplankton -- Illinois River

Table 2 shows that the number of zooplankters per liter in the main channel of the Illinois River apparently declined by a factor of 8 between 1898 and 1974. The number of rotifers had declined dramatically, while the copepods had increased slightly. Comparison of Kofoid's 1898 results with those of WAPORA (1974: E8) in 1973, show the same trends:

	Number Per Liter	
	1898[a]	1973[b]
Rotifera	386	36
Crustacea		
Branchiopoda		
Cladocera	2	13
Copepoda	c	11
Unidentified		26
Total	388	86

[a]Kofoid, 1904: 314-340.

[b]WAPORA, 1974: E8.

[c]Present in very small numbers.

The reasons for the decline of rotifers are not known, but one can speculate that the decline in phytoplankton and the increase in the suspended solids load of the lower Illinois River may have impaired the feeding of rotifers. Rotifers are an important food for the fry of many gamefish, such as bluegill, so the reductions noted above might have had a significant impact on the growth and survival of fish fry.

Benthos -- Illinois River

In 1915, Richardson (1921a: 490-493) took a total of seventy-three bottom samples between river miles 80.0 and 0.0. He used two types of iron dredges, which were hauled for distances of two or five feet along the bottom, and another device called a mud-dipper. He took care to determine the amount of bottom material and the number of organisms

Table 2

Comparison of Zooplankton Populations in the Main Channel of the Illinois River in 1898 and 1974, Under Stable Low-flow Conditions in September[a]

Major Taxonomic Divisions	Number of Species 1898[b]	Number of Species 1974[c]	Number of Individuals Per Liter 1898[d]	Number of Individuals Per Liter 1974[e]
Rotifera (rotifers)	29	10	386	25
Crustacea (crustaceans)				
Branchiopoda				
Cladocera (water fleas)	5	5	2	3
Copepoda (copepods)				
Calanoida	2	1	f	1
Cyclopoida	4	1	f	17
Harpacticoida	1		f	
Total	41	17	388	46

[a]Data were obtained from Kofoid, 1904: 314-340, and Colbert et al., 1975: F16-F20. Although Kofoid's samples were taken upstream of the study area, he conducted four studies (Kofoid, 1903: 273-283) of the longitudinal distribution of plankton in the river (one study included the lower 80 miles of the Illinois) and concluded that the plankton in the main channel was remarkably uniform. Hence, Kofoid's samples from the Havana area are probably generally representative of the main channel in the fall of 1898. Both Kofoid and Colbert et al. (1975) used no. 20 plankton nets. Kofoid also collected plankton on filter paper, but these results are excluded from the table because Colbert et al. did not use micro-filtration.

[b]The total number of species taken on Sept. 6, 13, 20, and 27, 1898 at one sampling station in the Illinois River near Havana (mile 128.5).

[c]The total number of species taken at six sampling stations (miles 23.1, 45.6, 57.6, 58.3, 77.0, and 81.0) in the lower Illinois River. The station at mile 2.5 was excluded because the number of species was much lower than at the other six stations.

[d]The total number of individuals taken in the four collections in September, 1898, was divided by four to obtain an average density.

[e]The total number of individuals taken at six locations (excluding the atypical results from river mile 2.5) was divided by six to obtain an average density.

[f]Present in very small numbers.

taken by each sampler in a series of parallel hauls, so that the results could be expressed in quantitative terms, as the number of organisms taken per unit of bottom area (Richardson, 1921a: 364). He also compared the efficiency of his sampling devices with a Petersen grab sampler, a device still used today (for example, see Colbert et al., 1975: 23).

In 1915, the study reach of the Illinois River had the lowest density and diversity of benthic organisms of any of the reaches Richardson studied (Richardson, 1921a: 404, 417). The biomass in this reach of the river was less than one twenty-fifth of the average in the lower 120 miles and less than one two-hundredth of the biomass in the vicinity of Havana (Richardson, 1921a: 410-412). Richardson (1921a: 474-475) gave the following reasons for the relative paucity of benthos in the study reach: (1) The bottom was well scoured and there was a lack of soft mud substrate due to higher current velocities, which in turn were attributable to a greater rate of fall in the main channel and confinement of the river between lateral levees. (2) The channel was dredged more frequently. (3) The absence of backwater areas (as a result of leveeing) concentrated the feeding activities of the annual upstream runs of large carp and buffalo in the spring.

On January 1, 1900, the Sanitary and Ship Canal was opened at Chicago, connecting the DesPlaines and Illinois Rivers with Lake Michigan. The canal was used to flush municipal and industrial wastes into the Illinois River system and away from Chicago's municipal water intake in Lake Michigan.

The quantity and quality of water diverted through the canal had tremendous impact on the Illinois River. Water levels at Havana, Illinois (river mile 120) rose an average of 2.8 feet and, during the normal low-flow period between June and September, rose 3.6 feet (Forbes and Richardson, 1919: 141).

After approximately 1910, as the pollution load increased, critically low dissolved oxygen levels in the water and putrescent

conditions in the bottom muds occurred further and further downstream with detrimental effect on food organisms and fish (Richardson, 1921b: 33-36, 75). Richardson believed that in the 1915-1920 period the area in which the bottom fauna was drastically reduced or obliterated was expanding downstream at the rate of 16 miles per year. By 1920, the bottom fauna in the river and bottomland lakes as far downstream as Browning (mile 97.0) had been affected. Between 1923 and 1925 there was a recovery in the benthos in the middle reach of the Illinois River (Richardson, 1928: 401-402).

Recent studies have shown that benthic populations in the middle reach of the Illinois River have again been reduced since the 1920's. Sparks (1975: 53-54) and Anderson (1977: 47-54) have described the die-off of fingernail clams in the middle reach of the Illinois River. Anderson (1977: 47-48) noted that mayflies were absent from the samples taken in the middle reach of the river. Benthic studies conducted at three power plant sites on the middle and lower sections of the Illinois River showed that the greatest diversity of organisms was obtained in the lower reach at Meredosia (mile 70.8).

Table 3 compares the average density of benthic organisms found by Richardson in river border and side channel habitats with the densities found in three more recent studies. Between 1915 and 1964 the number of midges and oligochaete worms increased dramatically, perhaps indicating that the organic load in the river had increased, while the average dissolved oxygen levels had slightly decreased. Between 1964 and the 1970's, the oligochaete worms and midges declined to intermediate levels, while the mayflies increased substantially -- these results probably indicate a decline in the organic load and an increase in the average dissolved oxygen level. The snails and fingernail clams increased between 1915 and 1964, as did the leeches, some of which prey on clams and snails. Fingernail clams generally thrive in

Table 3

Average Density of Benthic Organisms (Number Per Square Meter) in River Border and Side Channel Habitats Along the Lower 80 Miles of the Illinois River in 1915, 1964, 1974, and 1975[a]

	1915[b]	1964[c]	1974[d]	1975[e]
Turbellaria (flatworms)	0.2		2.7	
Hirudinea (leeches)	0.2	22	0.7	
Oligochaeta (worms)	2.6	2,579	184.6	245.4
Gastropoda (snails)	0.1	34		
Pelecypoda (clams)				
Sphaeriidae (fingernail clams)	10.4	52	35.4	19.4
Corbiculidae (Asiatic clams)			2.6	19.4
Unionidae (mussels)	1.0		1.1	
Insecta (insects)				
Odonata (dragonflies)	0.2		1.9	
Ephemeroptera (mayflies)	6.3	4	87.3	172.2
Coleoptera (beetles)			8.1	
Trichoptera (caddisflies)	2.2		3.4	2.2
Diptera (midges)	1.3	353	80.4	90.4

[a]Samples from the main channel were not used in computing the averages because no samples from the main channel were taken in 1975 and 1964.

[b]Richardson, 1921a: 490-493. Fifty-nine samples were taken in August. Averages reported for three reaches of the river between mile 0.0 and 80.0 were weighted according to sample size and then averaged.

[c]Starrett and Paloumpis, 1964, unpublished data in the files of the Illinois Natural History Survey at Havana. Ten samples were taken between river mile 19.3 and 30.8.

[d]Colbert et al., 1975: G15-G20. Nine samples were taken in September between river mile 81.0 and 2.5. Samples taken in side channels were included because side channels were sampled in the other surveys. One sample taken downstream from a dike was not included because this type of habitat was not sampled in the other surveys.
[e]Anderson, 1977: 23. Twenty samples were taken in August between river miles 58.0 and 18.9.

areas where there is a moderate amount of organic pollution and where soft mud bottoms are available.

Between 1964 and the 1970's, the fingernail clam populations declined slightly (the declines are very slight, and perhaps insignificant), Asiatic clams invaded the river, and the snails either disappeared entirely or were reduced to such low numbers that they did not show up in the recent collections. Asiatic clams were first found in the Illinois River in 1974 by Thompson and Sparks (1977: 34-36) and Colbert et al. (1975: G15-G19). The oldest Asiatic clams Thompson and Sparks found were 2- and 3-year-old clams, indicating that Corbicula first entered the Illinois River in 1970-1971. They may have been introduced in gravel delivered to a ferry landing at Kampsville (river mile 32). We do not know whether the Asiatic clam will displace or compete with the native sphaerid fauna (Thompson and Sparks, 1978: 391). Asiatic clams do not appear to be as nutritious a food for fish and waterfowl as the native fingernail clam, Musculium transversum, but the Asiatic clam may furnish a food source in portions of the Illinois River where fingernail clams have been eliminated by pollution (Thompson and Sparks, 1978: 394-395).

Table 4 shows that the same trends which occurred in the river border and side channel habitats between 1915 and the 1970's also occurred in the main channel: the midges, oligochaete worms, and mayflies increased, Asiatic clams appeared, and the snails disappeared. The increase in the numbers of organisms which burrow in the mud, such as the worms, midges, and burrowing mayflies (Hexagenia and Pentagenia), indicates that the construction of the dam at Alton may have reduced the current velocity and caused some deposition of mud in the main channel. Other studies have confirmed the absence of snails in the lower Illinois River. No snails were found in an intensive 2-year study at a power plant site at Meredosia (WAPORA, 1974: Appendix C15-C26). Butts (unpublished report, 1975: 4-5) found no snails in a benthic survey of Meredosia Lake. Some toxic agent present in the lower Illinois River may be eliminating the snails. Sparks and Walter (unpublished data)

Table 4

Average Density of Benthic Organisms (Number Per Square Meter) in the Main Channel of the Lower 80 Miles of the Illinois River in 1915 and 1974

	1915[a]	1974[b]
Turbellaria (flatworms)	0.6	
Hirudinea (leeches)		
Oligochaeta (worms)	3.1	37.0
Gastropoda (snails)	0.3	
Pelecypoda (clams)		
Sphaeriidae (fingernail clams)	2.4	3.5
Corbiculidae (Asiatic clams)		9.8
Unionidae (mussels)	0.1	
Insecta (insects)		
Odonata (dragonflies)	0.1	
Ephemeroptera (mayflies)	2.3	41.3
Coleoptera (beetles)		
Trichoptera (caddisflies)	6.6	
Diptera (midges)	0.6	53.8

[a]Richardson, 1921a: 490–493. Fourteen samples were taken in August between river mile 80.0 and 0.0. Averages reported for three reaches of the river between mile 0.0 and 80.0 were weighted according to sample size and then averaged.

[b]Colbert et al., 1975: G15–G20. Six samples were taken in September between river mile 81.0 and 2.5.

found that snails (Physa sp.), which were reared in the laboratory under conditions designed to reduce their exposure to pesticides as much as possible, rapidly accumulated dieldrin when exposed in cages to Illinois River water at mile 87 for a period of 8 days in August 1974. The dieldrin content of the snails increased significantly within 24 hours, and after 8 days the dieldrin content had increased from 0.1797 ppm wet weight, whole organism, to 0.8156 ppm. The increase in dieldrin content of the snails showed no signs of reaching a plateau within 8 days, so the ultimate equilibrium concentration of dieldrin in the snails was undetermined, but certainly much higher than 0.8 ppm.

Possible Effects of Barge Traffic on Benthos in the Illinois River. Colbert et al. (1975: 95) felt that the increase in benthic populations in the main channel of the Mississippi between a high-flow period in July of 1974 and an average-flow period in September 1974 indicated that barge traffic did not have a dominant influence on benthic organisms. Colbert et al. reasoned that the detrimental impacts of barges, if any, should be greatest under low-flow conditions. The data of Colbert et al. (1975: Table 6) for the benthic organisms in the Illinois River show no statistically significant differences in the populations between July (a period of high flows) and September (a period of low or average flows), except for a significant decline in the number of clams. The Illinois is a much smaller river than the Mississippi (the channel is shallower and narrower), and it is possible that barge traffic has a greater impact on benthic populations in the Illinois during low flows than in the Mississippi.

It is noteworthy that the turbidity and settleable solids were greater in the Mississippi than in the Illinois during high flows, but that both factors declined to a greater extent in the Mississippi than in the Illinois during low flows. The turbidity and settleable solids reflect the amount of suspended sediment in the river, and it may be that boat traffic more easily resuspends sediment in the Illinois during low flows than in the Mississippi. The disturbance of the bottom, or the resuspended sediment itself, may have detrimental effects on benthic

organisms. In addition, we do not know to what extent the resuspension of bottom sediments by barges in the main channel contributes to sedimentation in backwaters and bottomland lakes.

Biological, chemical, and sediment studies of Meredosia Lake were conducted in 1975 by the Illinois State Water Survey, the Illinois Natural History Survey, and the Illinois Geological Survey for the Illinois Department of Conservation and the U.S. Fish and Wildlife Service, which maintains a refuge at the lake. The sediment studies showed that Meredosia Lake is filling with sediment from the lower end, where the lake first becomes connected with the Illinois River when water levels rise from the normal pool elevation. The Illinois River essentially backs upstream into the lake when the water levels are at intermediate stages. When the river is at flood stage or above, the water flows across the low natural levees at the upper end of the lake, down through the lake, and out the downstream end. Butts (unpublished report, 1975: 7-8) found that the oxygen demand exerted by the sediment increased from the upstream end of the lake (2.58 grams/m^2/day, a value typical of an average polluted sediment in the main channel of the Illinois Waterway) to the downstream end (4.32 grams/m^2/day, which approaches the 5.00 grams/m^2/day observed in the grossly polluted upper Illinois Waterway). When the bottom sediments at the downstream end of the lake were disturbed, the oxygen demand was 86.08 grams/m^2/day, considerably higher than the demand observed anywhere else in the Illinois Waterway. In August 1974, the Natural History Survey found that oxygen levels in Meredosia Lake were 3 mg/1, while oxygen levels in the river on the same date were 6 mg/1. The readings were taken in the middle of the afternoon on an overcast day, and waves produced by a strong wind were resuspending bottom sediments in the lake. In the lake, a die-off of gizzard shad was occurring, and almost all the fingernail clams maintained in plastic cages on the bottom of the lake had died since they had last been checked in mid-July. The lake is devoid of submerged aquatic vegetation, and lakeshore residents have complained to their state legislators and to the Illinois Department of

Conservation about the very low populations of sport fish in the lake. See the section on sedimentation for further discussion of this problem.

Benthos — Mississippi River

Historical Perspective. Very little information is available concerning the status of benthic populations in the study reach of the Mississippi River prior to the construction of the navigation dams. Many of the early benthos studies that were conducted on other parts of the Mississippi prior to dam construction were concerned mainly with effects from the increased amounts of pollution entering the river.

At least one early study (Wiebe, 1927) has documented a reduction in benthic species diversity and an increase in pollution-tolerant forms. Presumably, similar consequences would have resulted from increased pollution in the study reach of the river. Another early study demonstrated the degradation of bottom fauna in Lake Keokuk (Ellis, 1931a) following closure of the dam.

Pre-Dam and Post-Dam Surveys. The earliest reported survey which includes benthos and was conducted near the study reach of the river is that of Garman (1890). He surveyed several sloughs, backwater areas, and bottomland lakes near Quincy, Illinois (river mile 327). He collected and identified 10 species of snails, 2 species of fingernail clams, 6 species of unionid clams, 6 species of chironomid larvae, and numerous other insect larvae. Many of the species Garman identified, including the snails *Valvata tricarinata* and *Lioplax subcarinatus* and the mayfly *Hexagenia bilineata*, were classified as clean-water species by Richardson in his study of the Illinois River (1928: 408, 409).

No other pre-dam benthic surveys were conducted in the region of the study area. However, in the section of the Mississippi from Minneapolis (river mile 850) to Winona, Minnesota (river mile 725) Wiebe documented a reduction in clean-water forms due to the influence of pollution from the Twin Cities (1927). Clean-water forms such as planaria and mayfly nymphs were first taken in this study below the Twin Cities at Red Wing, Minnesota (river mile 790). At this station fingernail clams, leeches, and tubificid worms numbered more than 1,700/m^2 (Wiebe, 1927: 146). In conjunction with these findings, Wiebe found more species of

benthic organisms (about 20) in unpolluted areas than in polluted areas (about 6) of the Mississippi River (1927: 166). Wiebe concluded that changes in the bottom fauna were primarily due to the lower dissolved oxygen content of polluted water (1927: 166).

Species Composition Changes. The lack of reliable pre-dam data concerning benthos in the study area prevents a comparison of pre- and post-dam species compositions.

Effects of the Navigation System on Benthos. Again, lack of historical data prohibits an analysis of the effects that construction of the navigation dams had on benthos in the study reach. Although historical data are available for Keokuk Pool, upstream from the study area, we do not feel that the effects of the high-head power dam at Keokuk are comparable to effects of the relatively low-head navigation dams in the study reach. The gates at the Keokuk dam are on the top of the dam, and the drop and the force of the water coming over the dam present an effective barrier to the movements of several species of fish. In addition, sediment accumulates readily above the Keokuk dam. In contrast, dams 24, 25, and 26 have gates which open from the bottom of the dam, and were purposely designed to pass sediment which would otherwise accumulate in the main channel immediately above the dam. During high flows in the spring, most of the gates are open from the bottom and are out of the water, and most fish which make upstream spawning migrations in the spring can probably negotiate these dams.

The operation and maintenance of the nine-foot channel also affects benthic organisms. Dorris and Copeland (1962: 246, 247) reported that winter drawdowns in the section of the Mississippi bordering Iowa, Illinois, and Missouri significantly reduced the mean numbers of mayfly naiads (Hexagenia rigida). Dredging operations destroy the benthos in the channel and spoil placement may smother benthic populations. We do not know how rapidly different types of benthic organisms can recolonize areas which have been dredged or have received dredge spoil.

A major study of the benthos in Pools 24, 25, and 26 of the Mississippi River and the lower 80 miles of the Illinois River was conducted by Colbert et al. (1975) in 1974 for the St. Louis District, U.S. Army Corps of Engineers. They took a series of benthic samples under high flow conditions in July and another series during average flow conditions in September. They generally sampled the following four habitat types at each of thirteen locations in the Mississippi River: main channel, side channel, river border area, and area downstream of dikes. Definitions of habitat types are given in Colbert et al. (1975: 16-17).

Colbert et al. (1975: 94-95) found that side channels and river border areas generally afforded the best habitat for benthic organisms, while the main channel was the poorest habitat. Total density of benthic organisms, species diversity, number of taxa, number of oligochaetes, oligochaete biomass, and total biomass (exclusive of clams) were significantly lower in the main channel. Colbert et al. (1975: 95) felt that relatively high current velocity and the coarse, shifting substrate in the main channel were the main factors limiting the benthic organisms. Colbert et al. (1975: 84) also found that the density of aquatic insects, and the average number of taxa and diversity of all benthic organisms in the Mississippi River were significantly greater in September during average flow conditions than in July when the flow was high. On the basis of these results, they reasoned that the effects of natural environmental conditions (current velocity, shifting substrate) in the main channel are more critical than the effects of river traffic, since the benthic organisms increased during low flow when effects from

river traffic would be expected to have the greatest impact. Since no one knows what the benthic populations would have been in the absence of river traffic, their conclusion should be regarded as tentative.

It is also possible that changes in the chemistry of the water and sediment in the Mississippi River between July and September, 1974 influenced the benthic organisms. For example, the dissolved oxygen concentration increased significantly, while the turbidity and settleable solids declined significantly. Both trends would favor benthic organisms. Benthic organisms live in or on the sediment, so the chemistry of the sediment would be expected to influence them. The concentration of certain toxicants, such as ammonia, zinc, and cyanide, declined significantly between July and September (Colbert et al., 1975: Table 6). More information on the relationship between physical-chemical factors and benthic organisms needs to be obtained before one can make a rational choice among the above alternative hypotheses.

Importance of Benthos as Food for Fish and Wildlife. Studies have been conducted by Iowa State University and the Illinois Natural History Survey on the use of benthic organisms by fish and waterfowl in Pool 19. The fingernail clam is an important food item in the diets of many fishes and diving ducks on Pool 19. Carp, gizzard shad, smallmouth buffalo, white sucker, and black bullhead feed extensively on fingernail clams (Jude, 1968: 227, 228, 229). Thompson (1969) estimated a daily consumption of 229 grams of sphaeriids (blotted with shell intact) per diving duck on Pool 19. This rate would have amounted to a sphaeriid harvest of over 2 million kg by ducks during both the spring and fall of 1967 (Gale, 1969: 149). Populations of fingernail clams in Pool 19 have reached over 100,000/m^2 (Gale, 1969: v).

While the study reach does not receive the intensive duck use that Pool 19 receives, significant populations of diving ducks do appear on Pool 26 in winters (December-January) when Pool 19 freezes over (personal communication, Frank C. Bellrose, Wildlife Specialist, Illinois Natural History Survey, Havana, Illinois, 1978). Colbert

et al. (1975: 613) found maximum populations of fingernail clams were only $268/m^2$ in Pool 24 but they may not have sampled areas where diving ducks are known to congregate and feed.

Recent Changes in the Benthos. Thompson and Sparks have documented a significant decline in the fingernail clam populations of Pool 19 during 1976 and 1977 (1978). While clam numbers during the fall migrations of 1973-1975 reached pool means (all stations) of $34{,}000$-$47{,}000/m^2$, the 1976 figure fell to $16{,}000/m^2$ and populations continued to be depressed through September, 1977 (Thompson and Sparks, 1978). The cause of the population decline is unknown but may be related to the low river discharge of 1976-1977 and a deterioration in water quality (Thompson and Sparks, 1978). The fingernail clam populations in the study reach of the river may have been similarly affected.

Commercial Mussel Fishery -- Illinois River

Historical Perspective. Comparison of mussel catch statistics before and after construction of the nine-foot channel first necessitates a brief historical sketch concerning the changing status of this fishery. The pre-dam mussel fishery passed through two phases: a pearl-hunting phase and a pearl-button-industry phase.

By 1890 people were hunting for pearls in Illinois waters and from 1889 to 1897 the pearl fisheries of the state produced at least $250,000 ($1,771,750 in 1977 dollars) worth of pearls (Kunz, 1897: 395). The Illinois River was not, however, a prominent pearl-hunting river of the state (Danglade, 1914: 8).

The first American fresh-water shells for button manufacture were probably taken from the Illinois River in 1872 and 1876 (Danglade, 1914: 7). Around 1910 more than 2,600 boats were being used for mussel fishing between Peru and Grafton (Danglade, 1914: 8).

Mussels have been taken from the Illinois River during the post-dam period for use in both button manufacture and, more recently, the pearl-culture industry. Renewed interest in the commercial harvest of freshwater mussels occurred in Illinois in the early 1960's in response to new markets established by the Japanese pearl-culture industry (Lopinot, 1968: 1; Starrett, 1971: 267). The pearl culturists round off chunks of freshwater shell, and insert them into salt-water pearl oysters. Over a period of several years, the pearl oyster deposits a thin layer of nacre over the nucleus furnished by the freshwater shell. Pearl culture requires starter material from thick-shelled mussel species only found in the Mississippi River, its major tributaries, and a river system in Red China (Lopinot, 1967: 15; Starrett, 1971: 267). The pearl-culture industry had obtained most of its shells from the Tennessee River system, but the decline of this resource led the industry to look elsewhere for shells (Starrett, 1971: 267).

Pearl-culture-related shell production from the Illinois River peaked in 1965 when 1,159 tons were harvested (Lopinot, 1968: 10). The supply of freshwater shells exceeded the demand by Japanese buyers for a number of years, and prices fell. While shells have not provided a worthwhile

income for Illinois fishermen since 1972, indications along the river are that the market may improve soon (Bellrose et al., 1977: C-117).

Pre- and Post-Dam Mussel Harvests. A comparison of reported mussel catches in pre- and post-dam construction years is difficult considering the paucity of available data. Also, harvest information by species is not available. Possible effects of the navigation system on the mussel catch will be discussed later.

The earliest reliable commercial mussel harvest information for the Illinois River is contained in a statement made by Danglade:

> The Illinois /River/ reached its maximum shell production during the season of 1909, when thousands of tons of good button shells were gathered and put in piles along the shore to await shipment. (1914: 8)

Danglade also found that in 1912 the mussel fishermen in the river from Kampsville (river mile 32.0) to Grafton (river mile 1.0) averaged a daily yield of 500-700 pounds of shells per man (1914: 23).

Other pre-construction years for which data are available are 1922 and 1931 (Table 5). While these figures compare favorably with the "thousands of tons" Danglade mentioned, the 1931 harvest represents a 62.5 percent reduction from the 1922 harvest.

Post-construction mussel catch information to 1963 shows harvests which are greatly reduced from 1922 and 1931 figures. However, with the advent of the pearl-culture industry, the mussel catch peaked in 1965 and 1966 to over 1,000 tons (Table 5). These figures are similar to pre-construction catches. This increased catch was short-lived and catch figures since 1968 are significantly reduced, with no reported catch since 1970. The catch was reduced after 1968 because the market had been glutted and the Japanese had stockpiled shell. The stockpiles have been reduced and the Japanese are buying

Table 5

Weight and Value of the Mussel Catch from the Illinois River, 1908-1970

Year	Pounds of Mussel Shells	Dollar Value of Mussel Shells	Value, 1977 Dollars
1908		139,000[a]	836,085
1913		128,692[a]	696,738
1922	2,759,000	68,500	267,561
1931	1,034,400	8,341	44,[illegible]
1956	30,000	450	967
1958	6,000	254	523
1963	900,000	22,500	43,495
1964	730,000	18,000	37,044
1965	2,318,000	75,335	152,026
1966	2,236,800	109,461	213,777
1967	776,960	38,848	75,715
1968	186,000	8,000	15,208
1969	663,000	43,000	78,690
1970	54,000	4,000	7,060

[a]Value of shells and pearls.

Sources:
1908 -- Danglade, 1914.
1913 -- Coker, 1921.
1922, 1931 -- U.S. Bureau of Fisheries, Report of the Commissioner of Fisheries, Administrative Report.
1956, 1958 -- Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service.
1965-1968 -- Lopinot, 1968.
1968-1970 -- National Marine Fisheries Service, U.S. Department of Commerce.

again, stimulating a recent (since 1975) revival in the mussel industry that is not yet reflected in the commercial statistics in Table 5, which were only available through 1970. The Tennessee Shell Company, thelargest buyer of shells, has not branched out into manufacturing novelty table tops with freshwater shells embedded in plastic,so perhaps the demand for shells will stabilize.

Species Composition Changes. An investigation of species records for the lower Illinois River since 1912 indicates the loss of several species from this stretch of the river (Table 6). The number of species recorded for Alton pool has been reduced from a total of 31 since 1912 to only 14 in 1966-1969: a loss of 17 species. However, fewer species have

Table 6

Kinds of Mussels Taken Alive from the *Illinois* River in the Vicinity of Meredosia in 1912, 1930, 1955, and 1966[a]

	Mussels Taken			
Kind of Mussel	1912[b]	1930[f]	1955[c]	1966[d]
F. ebena (Ebony Shell)	P[e]	P		
F. f. f. *undata* (Pig-Toe)	P			P
M. gigantea (Washboard)	P	P	P	P
A. plicata (Three-Ridge)	P	P	P	P
Q. quadrula (Maple-Leaf)	P	P	P	P
Q. pustulosa (Pimple-Back)	P	P	P	P
Q. nodulata (Warty-Back)	P	P	P	P
Q. metanevra (Monkey-Face)	P			
T. verrucosa (Buckhorn)	P	P	P	
C. tuberculata (Purple Warty-Back)	P			
P. cyphyus (Bullhead)	P			
P. coccineum f. *solida*	P			
E. crassidens (Elephant's Ear)	P			
E. dilatatus (Lady-Finger)	P			
A. confragosus (Rock Pocketbook)	P	P	P	P
L. complanata (White Heel-Splitter)	P			
A. grandis complex (Floater)	P	P	P	P
A. imbecillis (Paper Pond Shell)		P		
O. reflexa (Three-Horned Warty-Back)	P	P	P	P
A. ligamentina (Mucket)	P			
P. lineolata (Butterfly)	P			
T. truncata (Deer-Toe)	P	P	P	P
T. donaciformis (Fawn's Foot)	P	P	P	
L. fragilis (Fragile Paper Shell)	P	P	P	P
P. alata (Pink Heel-Splitter)	P		P	P
P. laevissima (Fragile Heel-Splitter)	P	P	P	P
C. parva (Liliput Shell)		P		
L. recta (Black Sand-Shell)	P			
L. a. f. *anodontoides* (Yellow Sand-Shell)	P	P		
L. a. f. *fallaciosa* (Slough Sand-Shell)	P	P	P	P
L. r. luteola (Fat Mucket)	P	P	P	
L. ventricosa (Pocketbook)	P			
L. o. f. *higginsii* (Higgin's Eye)	P			
Total	31	19	16	14

[a]Table taken from Starrett, 1971: 357.
[b]Collections by Danglade (1914: 37) at the old LaGrange lock and dam and at Meredosia.
[c]Collections made 2 miles above Meredosia in 1955 by Dr. Paul W. Parmalee (personal communication, 4 January 1968).
[d]1966 survey in the vicinity of Meredosia (river miles 70.8-79.8)(Starrett, 1971).
[e]P = present, blank = absent.
[f]Collections made in the early 1930's in the vicinity of Meredosia by Dr. J.P.E. Morrison (personal communication, 4 January 1968).

been eliminated from this pool than from other parts of the river (Starrett, 1971: 356).

A comparison of species records for pre-dam (1930) and post-dam (1955) years indicates the loss of 3 species from the river in the vicinity of Meredosia (Table 6). Specifically, the yellow sand-shell (L. anodontoides), liliput shell (C. parva), and the paper pond-shell (A. imbecillis) were present in 1930 but absent in 1955. Paper pond-shells were, however, collected below Meredosia (Naples -- river mile 65.5) in 1966 (Starrett, 1971: 356).

While the liliput shell and paper pond-shell are not of commercial value, the yellow sand-shell was an important commercial species. Danglade (1914: 45) in discussing the yellow sand-shell in the Illinois River (1912) stated:

> This species is found sparingly throughout the upper river, but is fairly abundant in the Hardin district, where it is in sufficient quantity to be sorted out and sold separately at an advanced price. This shell is the most valuable of the freshwater mussels . . .

The yellow sand-shell may still occur in Alton Pool as a rare species (Starrett, 1971: 357).

While the fat mucket (L. luteola) and fawn's foot (T. donaciformis) were found near Meredosia in 1955, they were not found there in 1966 (Table 6). A single specimen of the fat mucket was found in a commercial shell pile at Meredosia in 1966 and Starrett believed this species would soon be eliminated from the river (Starrett, 1971: 336). While the fawn's foot was not collected from Alton Pool by Starrett in 1966, it probably occurred there in small numbers (Starrett, 1971: 327).

As late as 1966 only the Alton Pool of the Illinois River supported relatively large populations of pimple-backs (Q. pustulosa) and washboards (M. gigantea) and moderate populations of warty-backs (Q. nodulata) and three-horned warty-backs (O. reflexa) (Starrett, 1971: 356). The predominant species taken by mussel fishermen from the Illinois River in the 1960's were the three-ridge (A. plicata) and washboard (M. gigantea) (Lopinot, 1968: 8).

Economic Factors Affecting the Commercial Mussel Fishery. Market changes have had a dramatic effect on the mussel industry of the Illinois River.

As mentioned previously, the early mussel fishery on the Illinois River was concerned primarily with pearl hunting. While it is not known what percentage of the early market is attributable to pearl products alone, Danglade (1914: 36) had estimated that average pearl slug yield for the river was one-half ounce per ton of shells, with the percentage of pearls per ton being much smaller. Occasionally, pearls of great value were found in the lower Illinois River with one at Pearl (river mile 41.8) worth $2,700 ($15,512 in 1977 dollars) and one found at Hardin (river mile 21.4) worth $750 ($4,309 in 1977 dollars) (Danglade, 1914: 36). The washboard (*M. gigantea*) was the principal pearl-bearing shell in the Illinois River and this mussel is still present in Alton Pool (Table 6).

Although shipments of shells for button manufacture were sent from Beardstown as early as 1876 (Danglade, 1914: 7), the shell-button industry did not develop extensively on the river until the early 1900's. In 1970 a button or blank factory was established on the river at Beardstown and the next year another plant was located at Meredosia (Danglade, 1914: 8). The average price of shells from the lower Illinois River was $25 per ton ($140 in 1977 dolalrs) in 1909. By 1912 there were 9 button factories on the lower river: 2 at Meredosia, 1 at Naples, 5 at Pearl, and 1 at Grafton (Danglade, 1914: 8). In the same year the average price paid for shells had dropped to $12-13 ($70-75 in 1977 dollars) per ton with high-quality shells such as ebony shells (*F. ebena*) and sand-shells (*L. recta*, *L. fallaciosa*, *L. anodontoides*) commanding $50-60 ($287-345 in 1977 dollars) per ton (Danglade, 1914: 12).

The "boom" in shell collection did not last and by 1911 over-harvesting, siltation, land reclamation, and pollution were affecting mussel populations (Forbes and Richardson, 1913; Danglade, 1914: 47, 48). From 1909 to 1912 the number of boats engaged in mussel fishing on the entire river fell from approximately 2,600 to 400 (Danglade, 1914: 8).

In this same period, the number of commercial mussel fishermen working between Meredosia and Naples fell from 200 to 25-35 (Danglade, 1914: 21). The total value of shells and pearls taken from the river dropped from $139,000 ($836,085 in 1977 dollars) in 1908 to $128,692 ($696,738 in 1977 dollars) in 1913 (Table 5).

Although the data are incomplete for the years following 1913, the values of the 1922 mussel catch and the 1931 catch were greatly reduced from previous years (Table 5). After World War II plastic generally replaced shell material in the manufacture of buttons. The mussel catch data for 1956 and 1958 follow the trend of previous years, showing greatly reduced harvests and values (Table 5).

From 1961 to 1966 the number of mussel-fishing licenses sold in Illinois rose from 69 to 1,279 (Lopinot, 1968: 6). A rise in mussel production paralleled the rise in license sales and the harvest from the Illinois River topped 1,000 tons in 1965 and 1966 (Table 5). The Wabash and Mississippi Rivers were the other main mussel-producing waters of the state during this period, with shells from the Wabash being of the best grade and commanding significantly higher prices (Lopinot, 1968: 10; Starrett, 1971: 268). During the revival of this fishery most of the shell beds fished commercially were located in Alton Pool (Starrett, 1971: 390). These beds possessed substantial standing crops of mussels (Starrett, 1971: 390).

By 1970 shell production had dropped to only 54,000 pounds from the entire river (Table 5). While a reduction in the kinds of mussels in the pool has taken place, this reduction did not affect the commercial catch significantly as the remaining species are the types favored by the pearl-culture industry. Although mussel fishing has not been economically worthwhile since 1972, the market has begun to improve recently, as mentioned previously.

Effects of the Navigation System on the Mussel Fauna. Specific effects of the navigation system on mussels are difficult to pinpoint as the river has been subjected to varying degrees of other potentially detrimental influences. According to Starrett, conditions for mussels in the Pool have generally worsened since 1930:

> . . . the mussel fauna of the Alton pool was affected adversely by pollution between 1912 and 1930 but . . . conditions for mussels probably have worsened since 1930 . . . (1971: 356)

Mussel populations in the lower Illinois River were being adversely affected prior to the completion of the navigation system. From 1912 to 1930 the number of species recorded from collections in the river near Meredosia fell from 31 to 19 (Table 6).

One early detrimental influence was the increased flow of sewage and industrial effluent from Chicago and Peoria as mentioned in the Water Quality Section. Although Alton Pool is the farthest removed from this influence, Starrett felt that upstream domestic and industrial pollution were the prime limiting factors for the mussels of this pool (1971: 356).

Overharvesting in the initial years of the pearl-culture industry also played a role. Danglade reported that as early as 1912 mussel fishermen near Meredosia complained that the "river is playing out," and in 1914 the area from Peoria south to Kampsville was depleted in output of mussels (1914: 17, 21).

Danglade (1914: 47) also felt that land reclamation was affecting the mussel resource:

> The levees which have been heretofore and are now being constructed, particularly in the lower stretches of the river, reduce to a large extent the breeding grounds of the valuable species of fishes and incidentally affect the future supply of the mussels /reduction of fish hosts/.

Between 1899 and 1914 in Illinois the bottomland areas protected by levees increased from 6,700 acres to 124,205 acres (Forbes and Richardson, 1919: 146). This trend continued and from 1920 to 1931 the levee acreage increased from 771,312 acres to 994,327 acres (Stewart, 1931: 37).

The current velocity of the Illinois River has been reduced, and Starrett attributes this reduction to the navigation dams and reduced diversion of Lake Michigan water from previous levels (Starrett, 1971: 272).

Diversion of water from Lake Michigan down the Illinois River was sharply curtailed in December 1938 (Chicago District, Corps of Engineers, 1975: 7), within the period the navigation dams were put into operation. We know of no way to separate the effects of reduced diversion from effects of impoundment on current velocity in the Illinois River. Forbes and Richardson found the usual rate of flow at normal stages to be 1½-2½ miles per hour (1920: xli). Starrett found the current speed in 1966 to be about 0.6 mph at normal stages. This reduction in current velocity compounded the siltation problem that already existed in the river (Starrett, 1971: 272; Bellrose et al., 1977: C-12). The reduced current velocity resulting from the dams and reduced Lake Michigan diversion may also be preventing the reestablishment of several mussel species:

> The navigation dams possibly have reduced the flow of the current enough to make the environment in the river unsuitable for the reestablishment of several current-inhabiting species of mussels present before 1900. (Starrett, 1971: 346)

Experiments by Ellis showed that most of the common fresh-water mussels were unable to maintain themselves in sand or gravel bottoms when a layer of silt from ¼" to 1" deep was allowed to accumulate on the bottom (1936: 39, 40). He found the yellow sand-shell to be one of the least resistant mussels he tested and while this mussel was not found alive in Alton Pool by Starrett in 1966 (1971: 356), it was collected in the Pool at Meredosia in pre-dam surveys (Table 6). Ellis also found that silt may reduce survival of young clams by destroying mucus threads used by the animal for anchoring (1931: 6, 7).

Starrett felt that sedimentation was of major importance in explaining the decline of the mussel fauna in the river:

> The increase in the sluggishness of the river, as mentioned above and the increased planting of row crops on the watershed have, in the author's opinion, made siltation in the past 30 years /mid-1930's to mid-1960's/ an important factor adversely affecting the survival of mussels and other organisms in the Illinois River and its bottomland lakes . . . (1971: 272)

The resuspension of bottom materials by barge traffic adds to the turbidity of river water. Starrett in 1964 found that in Alton Pool (river mile 65.1) the passage of two towboats increased the turbidity from 108 to 320 Jackson Turbidimeter Units (1971: 273). Increased turbidity and silt-laden water interfere with the feeding of mussels and in silty water mussels may remain closed 75-90 percent of the time (Ellis, 1936: 40).

The passing of barges can produce water level drawdowns which expose bottom-dwelling organisms such as insects, snails, and clams (Thompson and Sparks, unpublished). Following a protracted period of unusually high water levels in 1972 and 1973, an Illinois Natural History Survey crew examined a bed in the fall of 1974 at river mile 106.6 (upstream from the project area), where mussels were being regularly exposed as towboats passed, and where some mussels had recently died (Sparks, 1975a: 3).

Clams will close their shells and snails will withdraw into their shells when exposed this way, thus disrupting their normal activities such as feeding and respiration. If the animals do not open regularly to feed and respire, they will eventually die. Growth and reproduction are probably slowed by levels of disturbance that do not result in death. Some species of mollusks respond to gradually falling water levels by burrowing into the mud or retreating to deeper water. Based on our observations at mile 106.6, it seems that some mussels do not exhibit this adaptive response to repeated short-term exposures.

In conclusion, the mussel fishery in the study area of the Illinois River declined due to pollution and overharvesting prior to the completion of the nine-foot navigation system. The dams associated with the nine-foot channel and the reduction of diversion from Lake Michigan probably also affected the mussel fauna by reducing the current velocity and increasing sedimentation in some areas. Dredging and spoiling operations to maintain the navigation channel can destroy mussel beds. The increase in boat traffic which resulted from construction of the nine-foot channel has probably affected mussels. Barges resuspend bottom sediments, temporarily draw water away from shallow areas as they pass, and produce wave wash along the shores. Large pleasure boats also cause

pronounced wave wash along the shore. All these disturbances can adversely affect mussels.

Commercial Mussel Fishery -- Mississippi River

Historical Perspective. The history of the commercial mussel industry on the Mississippi River is similar to that of the industry on the Illinois River. On both rivers this industry was unstable. A number of factors, most notably overharvesting, resulted in a dramatic decline of this fishery shortly after its inception. As on the Illinois River, the establishment of new markets in the early 1960's led to a revival in mussel fishing. A map in Lopinot (1968: 7) shows that the Mississippi River above the confluence with the Missouri was fished commerically for mussels in the 1960's, so the 1960's revival in the commercial mussel fishery included portions of the study area.

Mussel fishing on the Mississippi River began about 1889 near Muscatine, Iowa. The fishery grew rapidly and by 1897 more than 300 people were engaged in mussel fishing on the Mississippi River between Burlington and Clinton, Iowa (Carlander, 1954: 40). By 1900 mussel fishing on the river had extended as far south as Grafton, Illinois (Townsend, 1902: 678).

Surveys on the river after 1899 indicated that mussel beds were declining (Carlander, 1954: 45). In response to the depleted condition of the resource, the Fairport Biological Station was established at Fairport, Iowa, in 1908 by the U.S. Bureau of Fisheries. The Fairport Station conducted research on mussel propagation but mussel harvests continued to decline. The degradation of mussel beds was generally attributed to overharvesting and increasing pollution (Carlander, 1954: 40, 41, 48). By 1946 there was very little mussel fishing in the Mississippi River below Muscatine and most of the shells worked by the button plants in Iowa during the 1950's were shipped in from Tennessee and Arkansas (Carlander, 1954: 51).

As on the Illinois River, the pearl-culture industry markets that were established in the early 1960's led to an increase in commercial mussel fishing activity on the Mississippi River. However, the rise in mussel harvests on the Mississippi did not reach the level attained on the Illinois and Wabash Rivers during this period (Lopinot, 1968: 10).

Pre- and Post-Dam Mussel Harvests. Early mussel-harvest information for the Mississippi River is sketchy but it is obvious that this

industry underwent phenomenal growth in the 1890's. Although little harvest information for individual species is available, the total mussel harvest for the river increased from 148,000 pounds in 1894 to more than 16 million pounds in 1899 (Table 7). In 1901 a shipment of approximately 1.5 million pounds of shells, comprised mostly of ebony shells and "sand shells", left Hannibal, Missouri (Townsend, 1902: 707).

The only other pre-dam year for which data are available is 1922. Although the catch for the entire river was greatly increased over previous data, the catch from the river by Illinois fishermen was significantly reduced from their 1899 share of the catch (Table 7). As the depletion of the initial mussel fishing areas around Muscatine increased, this fishery spread into Wisconsin, Minnesota, and Missouri (Cohen, 1921: 39) and the increased catch by fishermen from other states accounts for Illinois fishermen taking a reduced proportion of the Mississippi River catch.

Mussel harvests in post-construction years were greatly reduced from earlier figures (Table 7). While post-construction data are only available since 1955, it appears that the commercial mussel industry faltered earlier:

> . . . by the 1930's the mussel industry on the Mississippi River was dead. . . . The finishing touch came when plastic buttons were introduced onto the market. (Nord, 1967: 192)

As on the Illinois River, the Japanese pearl-culture markets of the 1960's stimulated increased mussel fishing on the Mississippi River. Peak production during this period lasted only a year or two with Illinois fishermen taking over 2,000,000 pounds from the Mississippi in 1966 (Table 7). Interestingly, this figure is comparable to the harvest taken from the Illinois River in the same year (Table 5). These new markets also stimulated musseling activity on the Mississippi River by Missouri fishermen. Harvests by Missouri fishermen from the Mississippi River peaked in 1965 and 1966 at over 100,000 pounds (Table 7). This increased harvest from the river was short-lived and harvest figures since 1967 are significantly reduced from those of the earlier

Table 7

Weight and Value of the Mussel Catch, Mississippi River and Associated Waters, 1894-1972

	State of Illinois			Illinois Catch from Mississippi R.		
Year	Pounds	Value, $	1977 $	Pounds	Value, $	1977 $
1894	47,500	665	5,248			
1899	8,910,000	43,468	314,926	8,910,000	43,468	314,926
1908						
1922	9,265,000	264,395	1,032,727	468,000	11,436	44,669
1955	18,000	90	200			
1956	44,000	770	1,655			
1957	9,000	1,000	2,089			
1958	22,000	1,000	2,060			
1959	100,000	2,000	4,112			
1960	400,000	14,000	28,756			
1961	100,000	3,000	6,186			
1962	400,000	16,000	32,896			
1963	1,812,000	73,000	150,526			
1964	1,358,000	59,000	121,422			
1965	1,750,000	85,000	171,530	362,000	75,335	152,026
1966	4,165,000	271,000	529,263	2,489,000	130,806	255,464
1967	1,560,000	130,000	253,370	148,000	66,870	130,330
1968	328,000	23,000	43,723			
1969	1,340,000	81,000	148,230	545,500	30,003	54,905
1970	125,000	11,000	19,415			
1972	8,000	<1,000	<1,638			

Sources:
1894 -- Smith, 1898
1899 -- Townsend, 1902; Carlander, 1954
1922 -- Sette, 1925
1955-1965 -- Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service
1965-1968 -- Bureau of Commercial Fisheries, National Marine Fisheries (Missouri, Mississippi River
1965-1968 -- Lopinot, 1968 (Illinois)
1969-1972 -- National Marine Fisheries Service, U.S. Department of Commerce

Sheet 1 of 2

Table 7 (concluded)

	Missouri Catch from Mississippi R.			Mississippi River		
Year	Pounds	Value, $	1977 $	Pounds	Value, $	1977 $
1894				148,000	2,072	16,350
1899				>16,000,000	66,110	478,967
1908					686,000	4,126,290
1922				51,768,173	1,050,600	4,103,643
1955				1,106,000	27,000	59,940
1956				500,000	20,000	42,980
1957				740,000	15,000	31,335
1958				124,000	3,000	6,180
1959				66,000	2,000	4,112
1960				386,000	6,000	12,324
1961						
1962				2,000	<1,000	<2,056
1963				46,000	1,000	2,062
1964				174,000	5,000	10,290
1965	108,000	4,000	8,072	1,326,000	39,000	80,262
1966	106,000	5,000	9,765	3,925,000	185,000	361,305
1967	50,000	2,000	3,898	263,000	12,000	23,338
1968	1,000	<1,000	<1,901	1,000	<1,000	<1,901
1969				1,388,000	76,000	139,080
1970				309,000	21,000	37,065
1972						

Sheet 2 of 2

peak years. Collections in 1975 and 1976 indicate that mussels are not abundant in Pools 24, 25, and 26 (Perry, in press: 6).

Species Composition Changes. The species composition of the mussel fauna of the Mississippi River has changed little from the pre-dam era (Table 8), but the relative abundance of certain species has been reduced. There are few data on the species changes that have occurred in Pools 24, 25, and 26 of the river.

Evidently, the ebony shell mussel (*Fusconaia ebena*) was once very abundant in Pools 24, 25, and 26 as well as the entire river (Townsend, 1902: 707; Cohen, 1921: 22; Nord, 1967: 191). A shell sample from the Mississippi River at Grafton, Illinois, in 1912 consisted of 32 percent ebony shells (Danglade, 1914: 25). This mussel was an important commercial species, taken for the pearl button industry (Smith, 1899; Townsend, 1902: 707; Coker, 1921: 41; Nord, 1967: 193). The known fish host for this mussel is the skipjack herring (*Alosa chrysochloris*), a fish that is supposedly migratory (Coker et al., 1921: 153; Starrett, 1971: 289). It appears that the construction of dams on the Mississippi River inhibited the movements of this fish (Coker, 1914: 23, 26; Barnickol and Starrett, 1951: 323) and in doing so reduced the survival of the ebony shell mussel. By 1926 the skipjack was no longer found above Keokuk Dam (Carlander, 1954: 48) and Barnickol and Starrett (1951: 323) report that skipjack herring were only taken occasionally in their collections from the river between Caruthersville, Missouri, and Warsaw, Illinois, in 1944. Nord summarizes:

> The importance of the three-ridge in today's fishery is an indication of the changes that have occurred in the clam population of the Mississippi River over the years. In the early days the ebony shell was the backbone of the industry, but this species has today nearly disappeared from the fishery. (1967: 193)

The UMRCC survey (Perry, in press: 8) classified the ebony shell as uncommon in the river.

Table 8

Mussel Species Reported from Mississippi River in 1906, 1931, and 1975-76

Species[a]	1906[b]	1931[c]	1975-76[d]
Cumberlandia monodonta	x[e]	x	
Fusconaia ebena	x	*[f]	*
Fusconaia flava f. *undata*	x	*	*
Megalonaias gigantea	x	*	*
Amblema plicata	x	*	*
Quadrula quadrula	x	*	*
Quadrula pustulosa	x	*	*
Quadrula nodulata	x	*	*
Quadrula metanevra	x	*	x
Tritogonia verrucosa	x	*	x
Cyclonaias tuberculata	x	x	x
Plethobasus cyphyus	x	*	x
Pleurobema cordatum	x	x	
Elliptio crassidens	x	x	
Elliptio dilatatus	x	x	x
Arcidens confragosus	x	*	x
Lasmigona costata	x		
Lasmigona complanata	x	*	x
Anodonta grandis Complex	x	*	*
Anodonta imbecillis	x	*	x
Anodonta suborbiculata	x		x
Alasmidonta marginata	x	x	

[a]Nomenclature follows Starrett, 1971.
[b]Baker, 1906.
[c]Ellis, 1931a.
[d]Perry, in press.
[e]x=collected in Mississippi River.
[f]*=collected in Pools 24, 25, and 26.

Sheet 1 of 2

Table 8 (concluded)

Species	1906	1931	1975-76
Strophitus undulatus	x	x	*
Simpsoniconcha ambigua		x	
Obliquaria reflexa	x	*	*
Obovaria olivaria	x	*	*
Actinonaias ligamentina	x	*	x
Actinonaias ellipsiformis		x	
Plagiola lineolata	x	*	*
Truncilla truncata	x	*	*
Truncilla donaciformis	x	*	*
Leptodea fragilis	x	*	*
Leptodea leptodon	x		
Proptera alata	x	*	*
Proptera capax	x	*	*
Proptera laevissima	x	*	*
Carunculina parva	x	x	
Ligumia recta	x	*	*
Ligumia subrostrata	x		
Lampsilis anodontoides f. anodontoides	x	*	*
Lampsilis anodontoides f. fallaciosa	x	*	*
Lampsilis radiata luteola		x	*
Lampsilis ventricosa	x	x	*
Lampsilis orbiculata f. orbiculata	x	x	
Lampsilis orbiculata f. higginsii	x	x	*
Number of species collected in Mississippi River in 1906, but not in 1975-76			9
Number of species collected in Mississippi River in 1931, but not in 1975-76			8
Number of species collected in Pools 24, 25, and 26 in 1931, but not in 1975-76			7

Sheet 2 of 2

Another commercial species which seems to have been adversely affected by dams is the yellow sand-shell (Lampsilis anodontoides a.). Smith (1899) listed this mussel as the second most important commercial species and "sand shells" were being taken from the river in significant quantities in the early 1900's (Townsend, 1902: 707). While Coker found good-sized beds of yellow sand-shells in Keokuk "Lake" in 1926, Ellis surveyed the same sites in 1931 and found no live yellow sand-shells and that the beds were covered with silt and "foul-smelling mud" (1931: 8). Ellis, as previously noted, found that the yellow sand-shell was readily killed by silt deposition (1936: 40). The known host fish for the yellow sand-shell is the long-nosed gar (Lepisosteus osseus) (Coker et al., 1921: 152; Baker, 1928, as seen in Parmalee, 1967: 101). Populations of this fish in the study reach of the river appear to be stable (see the section on the commercial fishery).

Economic Factors. In contrast with the mussel industry on the Illinois River, pearl-hunting never assumed financial importance on the Mississippi River (Nord, 1967: 191) and little is on record concerning this aspect of the industry. The value of the 1899 Illinois fishermen's catch from the Mississippi River of $43,468 ($314,926 in 1977 dollars) includes $1,425 ($10,324 in 1977 dollars) worth of pearls (Townsend, 1902: 683). In 1922 pearls and slugs accounted for $1,370 ($5,351 in 1977 dollars) of the $11,436 ($44,669 in 1977 dollars) value of the Illinois mussel catch from the Mississippi River (Sette, 1925: 226).

By 1899 there were 322 Illinois mussel fishermen working the Mississippi using $2,144 ($15,533 in 1977 dollars) worth of crowfoot lines, rakes, and other mussel fishing equipment (Townsend, 1902: 679, 680). This work force of 322 accounts for approximately 13 percent of the 2,389 people employed statewide in fishing that year and for 28 percent of the Illinois fishermen working the Mississippi River (Townsend, 1902: 678). In addition, the button-blank factories of Illinois employed 293 people in 1899 (Townsend, 1902: 678). Prices paid for shells in 1899 ranged from $8-10 ($58-72 in 1977 dollars) per ton. It is obvious that mussel fishing on the Mississippi River during this period was economically viable.

By 1922 the Illinois portion of the Mississippi River mussel fishery had been reduced, due to the northern and southern expansion of this industry into other states, as mentioned previously. In that year there were only 387 people from Illinois employed in all types of fishing on the Mississippi River (Sette, 1925: 193) compared to the 322 Illinois mussel fishermen on the Mississippi in 1899. The reported equipment used by Illinois mussel fishermen on the river in 1922 amounted to only 82 crowfoot bars valued at $395 ($1,543 in 1977 dollars) (Sette, 1925: 222). These figures coincide with the reduced Illinois proportion of the Mississippi River mussel catch in that year (Table 7). Examination of catch weight and values for 1922 show that prices paid for shells ranged from $40-60 per ton ($156-234 in 1977 dollars), so the demand for shells had raised prices above the 1899 levels but the supply of suitable mussels had evidently fallen due to over-harvest.

The shell processing and button-cutting aspect of the industry also lends insight to the economic importance of the industry. In 1898 there were at least 21 towns in Iowa and Illinois with button factories (Smith, 1899: 303). By 1922 there were 16 separate plants in Illinois employing 455 people (Sette, 1925: 193). In that year these plants produced over 2 million button blanks worth $454,613 ($1,775,718 in 1977 dollars) (Sette, 1925: 193). The by-products from these plants, which included poultry grit and stucco, were valued at $3,794 ($14,819 in 1977 dollars) (Sette, 1925: 193).

While the production of buttons from factories in Illinois, Iowa, and Missouri had remained stable from 1939 through 1948, most of the shells used in production during this time were imported from Tennessee and Arkansas (Carlander, 1954: 51). By the mid-1960's the last pearl-button factory at Muscatine closed as the industry could no longer compete with the low cost of plastic buttons (Parmalee, 1967: 4).

Recent Trends. The renewed interest in mussel fishing which resulted from the pearl-culture industry markets of the 1960's not only resulted in an increase in the number of mussel fishermen and in the catch (Table 7; Lopinot, 1968: 6), but also changed the species of

mussels fishermen sought. The pearl-culture fishery required thick-shelled mussels of the genera Amblema, Quadrula, Pleurobema, and Megalonaias (Cahn, 1949: 49, in Starrett, 1971: 267). The interest in these mussel species is fortunate as some of those valued as pearl-button stock, such as the ebony shell and yellow sand-shell, probably were not available in quantities to sustain the increased harvests brought by the pearl-culture industry. The Illinois catch from the Mississippi River during 1965-1967 was comprised mostly of washboards (Megalonaias g.) (75-80%) and three-ridges (Amblema p.) (15-20%) (Lopinot, 1968: 8).

The pearl-culture-related harvest did not last and during 1967 shell production dropped drastically (Table 7). This reduction was the result of the Japanese requiring larger shells and possible over-harvesting in 1966 (Lopinot, 1968: 19). During this period the market price paid for shells was $40-60 per ton ($78-117 in 1977 dollars) (Nord, 1967: 187; Lopinot, 1967: 12).

Effects of the Navigation System on the Mussel Fauna. The possible effects that the navigation system has had on the mussel fauna of the study reach are probably very similar to those outlined for the Illinois River (see Illinois section). The potentially adverse effects that the navigation system could have on the mussel fauna of the Mississippi River were recognized early when the Fisheries Service stated in their March, 1930 bulletin that the proposed nine-foot channel would be detrimental to clams (Carlander, 1954: 48).

Nord (1967) stated that the Mississippi River dams have slowed the current and facilitated deposition of sediment:

> The navigation dams have slowed down the current and silt deposits have smothered many formerly productive beds (of mussels). (Nord, 1967: 194)

The dams have also restricted the movements of at least one fish, the skipjack herring (Alosa chrysochloris), which serves as host for the formerly important ebony shell mussel. According to Barnickol and Starrett:

> The scarcity of the skipjack in the collections of the 1944 survey tends to indicate that this fish may have been affected by the locks and dams constructed below Keokuk . . . (1951: 323)

The restriction of this fish, which is uncommon in the study reach, has adversely affected the ebony shell population. It is possible that restrictions of the movements of other species of fish which serve as mussel hosts have reduced mussel populations (Coker, 1914: 8; Ellis, 1931: 6; Parmalee, 1967: 13).

Dredging, deposition of spoil, and barge traffic might have detrimental effects like those already described for the Illinois River. Because the Illinois is narrower, shallower, and has a predominantly mud, rather than sand bottom, the effects of boat traffic may be more pronounced in the Illinois than in the Mississippi.

Commercial Fishery -- Illinois River

Historical Perspective. In 1899, 600 rail carloads of fish were shipped from the Illinois River to New York City (Bartlett, 1900). Each car held from 8,000 to 20,000 pounds of fish. Twenty-two railcars were shipped from Beardstown alone (Townsend, 1902). By 1908, the value of the catch of freshwater fish from the Illinois River exceeded that of any other river in America (excluding rivers with anadromous fishes). The Illinois River catch was 10% of total freshwater fish production in the United States. Over 2,000 commercial fishermen found employment on the river in 1908 (Department of Commerce and Labor, 1911: 24, 34-41, 115).

In 1976, only 2 full-time commercial fishermen worked on the Illinois River, and the 1973 harvest was only 0.32% of the total U.S. harvest of freshwater fish (Department of Commerce, 1976). There were several factors responsible for the decline of the commercial fishery. Economic factors were important, as mentioned in the section on commercial fisheries in the Mississippi River. For example, at the turn of the century, there were many European immigrants to the United States who preferred carp as a food. The descendants of these immigrants prefer other types of food, so the demand for carp has declined (Sullivan, 1971: 65-79). The development of refrigeration techniques permitted inland marketing of saltwater fish, which probably began to compete with locally-caught freshwater fish.

However, if economic factors alone were responsible for declines in the freshwater commercial fishery, then similar declines should have occurred in all Midwestern rivers. Table 9 shows that the harvest of fish from the Mississippi River has remained relatively constant since 1950, whereas the harvest from the Illinois River has declined drastically during the same period. During the same period the number of full-time commercial fishermen on the Mississippi River bordering Illinois declined by 73%, compared to a 98% decline on the Illinois River. Table 10 shows that with the exception of carp, the wholesale price for fish (in 1977 dollars) has been rather constant or has actually increased from the turn of the century.

Commercial fishermen and market operators along the Illinois River

Table 9

Summary of the Commercial Catch of Fish from the Illinois River and the Mississippi River Bordering Illinois, and the Number of Full-Time Fishermen, 1950-1974

	Catch (in thousands of pounds)		Full-Time Fishermen	
Year	Illinois R.	Mississippi R.	Illinois R.	Mississippi R.
1950	5,760	2,923	106	122
1954	3,430	2,726	111	135
1955	4,006	3,893	96	125
1956	3,218	3,310	88	130
1957	2,791	3,224	105	133
1958	2,871	4,208	70	131
1959	2,639	4,349	61	137
1960	2,260	4.224	69	118
1961	2,215	3,175	65	115
1962	2,205	3,464	50	98
1963	2,240	3,669	48	76
1964	1,581	3,238	56	62
1965	1,449	3,470	44	78
1966	1,624	3,455	23	80
1967	1,869	2,904	43	75
1968	1,522	2,670	38	56
1969	1,911	2,889	30	48
1970	919	3,178	22	59
1971	1,327	3,041	9	54
1972	655	3,247	13	75
1973	399	3,610	13	79
1974	571	3,375	15	90
1975	474	3,371	1	51
1976	433	2,467	2	33

Note: Most of the statistics were obtained from statistical digests published by the U.S. Department of Commerce. The 1972-1976 data and the number of full-time commercial fishermen on the two rivers were provided by Mr. Larry Dunham, Staff Fisheries Biologist, Special Projects, Illinois Department of Conservation.

Table 10

Calculated Wholesale (Undressed) Prices Paid to Illinois River Commercial Fishermen for Catches of Carp, Buffalo, Channel Catfish, and Freshwater Drum in 1894, 1899, 1922, 1931, 1950, 1955, 1960, 1965, and 1970[a]

	Carp		Buffalo		Channel Catfish		Freshwater Drum	
Year	$/lb.	1977 $/lb.[b]	$/lb.	1977 $/lb.	$/lb.	1977 $/lb.	$/lb.	1977 $/lb.
1894	.026	.205	.024	.189	.037	.292	.018	.142
1899	.026	.188	.027	.196	.036	.261	.021	.152
1922	.045	.176	.064	.250	.148	.578	.067	.262
1931	.024	.124	.049	.254	.092	.477	.051	.264
1950	.041	.098	.093	.222	.205	.489	.095	.226
1955	.040	.089	.090	.200	.240	.533	.070	.155
1960	.048	.099	.098	.201	.250	.514	.080	.164
1965	.044	.089	.085	.172	.215	.434	.063	.127
1970	.055	.097	.116	.205	.272	.480	.076	.134

[a]Obtained from Bellrose et al. (1977: C-108-C-109, Table C-38) by dividing the dollar value of the catch by its weight in pounds.

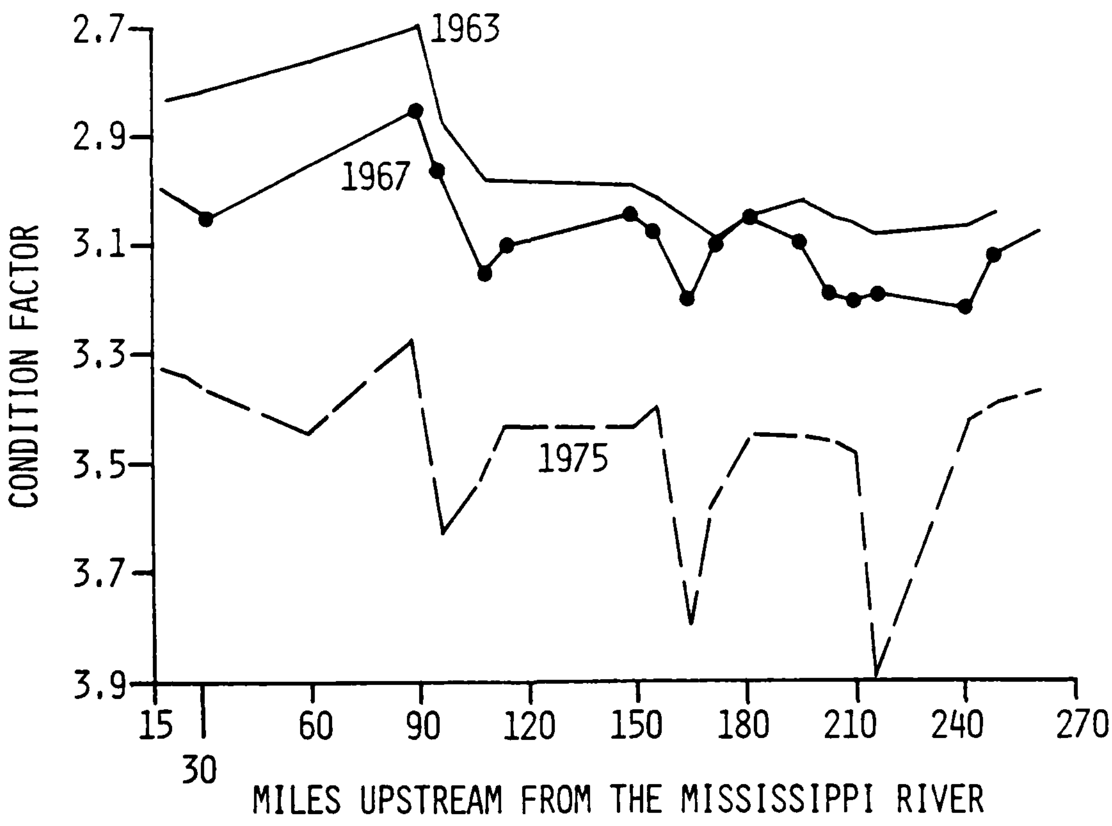
[b]Obtained by using conversion factors in Table 19.

were interviewed in 1977, as part of another project (Bellrose et al., 1977: B8-B9). These interviews indicated there is a demand for fish along the Illinois River which currently cannot be met from the Illinois River fishery. For example, Dixon's Fish Market on Peoria Lake (a main stem lake on the Illinois River upstream from the study area) purchases carp from Wisconsin for use in their fee-fishing areas and channel catfish from fish farms in Arkansas for wholesale and retail trade. Mr. A.T. Nelson, who operates a market on the Illinois River at Pearl (within the project area, river mile 43.2), buys carp and buffalo from the Mississippi River and sea food.

When market operators and commercial fishermen are asked why the markets do not buy fish from the Illinois River, the most frequent reply is that there are fewer large fish in the river than formerly, and the remaining fish are in relatively poor condition. Most of the younger commercial fishermen along the Illinois River work only part-time at commercial fishing. They also use pickup trucks and trailerable boats to range widely over the states of Illinois and Iowa to take advantage of fishing opportunities in reservoirs and in the Mississippi River. Although they live along the Illinois River, because their families grew up there, they report that their catches in the Illinois do not bring as great a return for their time, gasoline, and equipment expense, as their catches elsewhere.

The loss of backwater habitat due to draining and sedimentation has affected the commercial fisheries in some sections of the river (Bellrose et al., 1977: C107-C115). However, the major drainage projects were completed in the 1920's (Mills et al., 1966: 5) yet the commercial fisheries in the Illinois River have continued a steady decline up to the present (Table 9). Drainage and leveeing were most extensive within the project area of the Illinois River, leaving little more than a main channel and side channels (except for Meredosia Lake at the upstream end and several lakes and backwaters between the mouth and river mile 15), yet the remaining commercial fishing became concentrated in this reach of the river because the carp were generally in better condition and more marketable (Figure 3) and legal-size catfish were more abundant (Sparks, 1975: Table 21) than in other reaches. Habitat loss alone

Figure 3. The condition factor of carp, Cyprinus carpio, in the Illinois River in 1963 was much better downstream from river mile 80 -- a reach of the river where fish food organisms such as fingernail clams, snails, and mayflies occurred. Channel catfish were also more abundant in the lower Illinois River (Sparks, 1975b: Table 21). The condition factor of carp was poor above mile 80, where the fingernail clams had died out in the 1950's. The condition factor of carp in 1967 showed the same pattern, but an overall decline had occurred, with more pronounced declines at river miles 95-105, 160-170, and 200-240. By 1975, the overall condition of the carp in the river had further declined, and localized declines had become more severe. The general decline in carp condition between the 1960's and 1970's was associated with a decline in the abundance of some food organisms, such as snails, fingernail clams, and mayflies in the lower river. The causes for the localized declines in carp condition are not known.
Source: unpublished data in the files of the Illinois Natural History Survey.



cannot explain the decline in the condition of commercially important species such as carp.

A decline in the size and condition of commercial fish indicates a problem in the food supply. Starrett (1972: 151) studied the food habits of carp in the Illinois River in the 1960's and found that in the study reach of the Illinois River fingernail clams comprised 50% of the volume of food items in carp stomachs, whereas in the middle and upper reaches of the river only one fingernail clam was found in all the stomachs examined. Figure 3 shows that in 1963 the condition factor of carp was considerably better in the study reach of the Illinois River than in the middle and upper reaches. More recent data used in Figure 4 show that there was a good correlation between condition factor of carp and the total abundance of bottom fauna in the Illinois River in 1975. Figure 3 demonstrates that there has been a general decline in the condition factor of carp in the whole Illinois River since 1963.

Prior to the 1950's the greatest harvest of commercial fish generally occurred along the middle reach of the Illinois River (mile 80.2 to mile 210), in areas where food organisms, such as fingernail clams, were most abundant (Richardson, 1921b: 462-465). Paloumpis and Starrett (1960) documented a die-off of fish food organisms in this reach of the Illinois River in the mid-1950's (see the section of this report on Illinois River benthos). Some unidentified factor apparently eliminated the fingernail clam and other benthic organisms from the middle reach of the Illinois River, with a consequent effect on bottom-feeding species of fish, many of which are commercially important, such as carp, buffalo, and drum. In contrast to the middle reach of the river, the commercial harvest from the study reach of the river has been relatively constant since 1950 (Table 11). Starting in 1962, the study reach has consistently ranked second in production among the four pools with commercial fisheries (Table 11).

An annual electrofishing survey of the Illinois River by the Illinois Natural History Survey has shown that the number of channel catfish taken from the Alton Pool of the Illinois River consistently

Figure 4. RELATIONSHIP BETWEEN CONDITION FACTOR OF CARP AND BOTTOM FAUNA IN THE ILLINOIS RIVER IN 1975

Source: Unpublished data in the files of the Illinois Natural History Survey.

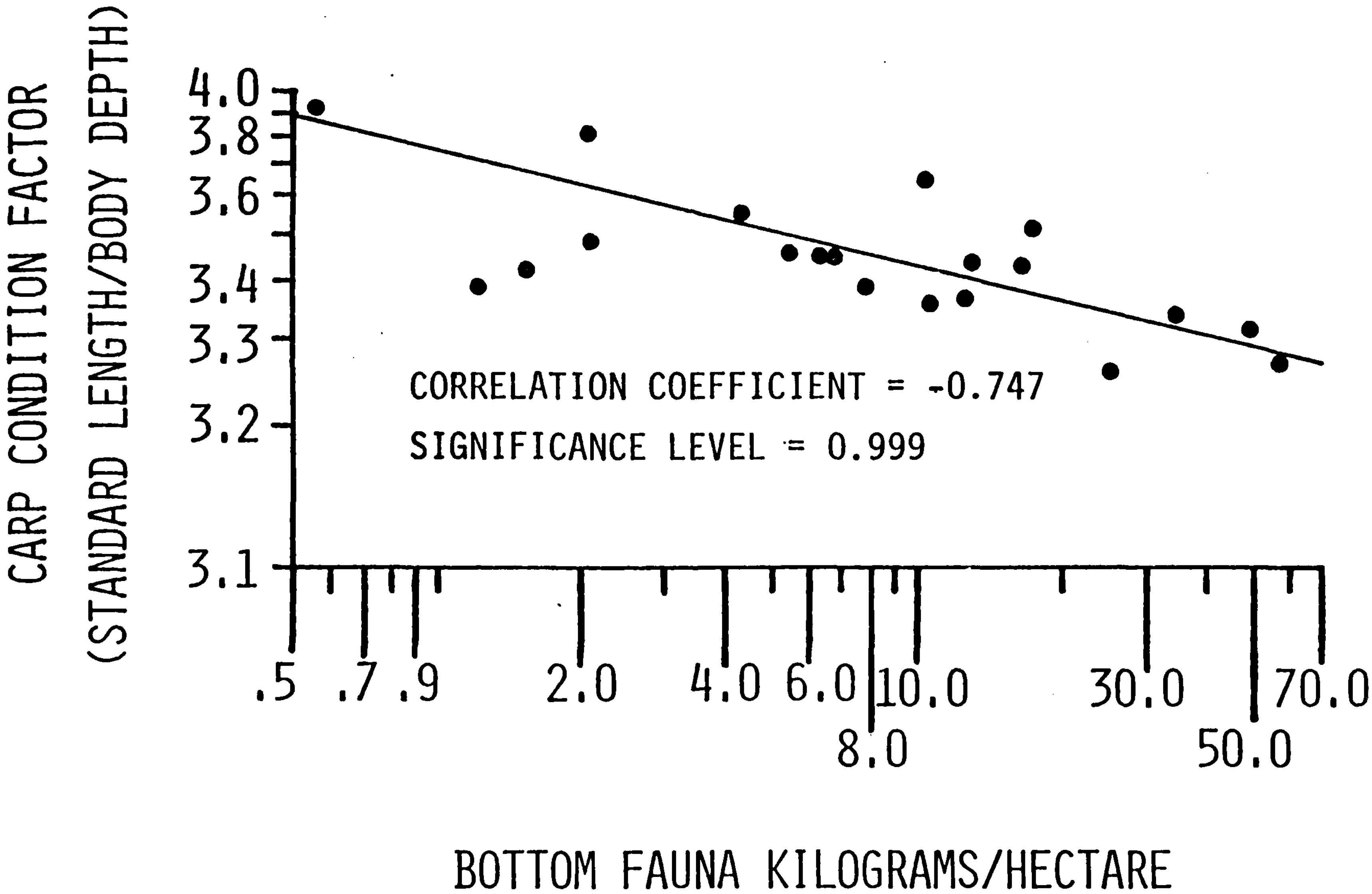


Table 11

Yearly Total and 5-year Average Harvest (in Pounds) of Carp, Buffalo, Channel Catfish, Freshwater Drum, and All Commercial Species from Alton Pool, Illinois River, 1950-1970[a]

Year	Carp	Buffalo	Channel Catfish	Freshwater Drum	Total[b]
1950 (3)[c]	241,488	172,629	43,119	41,684	527,890
1951 (3)	203,818	89,817	29,190	21,030	354,983
1952 (3)	142,202	30,120	9,346	7,719	191,826
1953 (3)	638,510	315,414	54,817	77,069	1,123,901
1954 (3)	385,493	222,319	68,922	86,598	766,993
1950-1954 avg.	322,302	166,060	41,079	46,820	593,119
1955 (2)	654,696	352,652	105,628	164,297	1,284,191
1956 (2)	668,038	204,362	115,936	95,917	1,115,580
1957 (3)	336,812	136,266	72,393	41,511	595,873
1958 (3)	324,168	103,167	67,845	59,654	561,004
1959 (3)	345,951	100,703	62,516	29,629	549,723
1955-1959 avg.	465,933	179,430	84,864	78,202	821,274
1960 (2)	350,712	184,330	46,395	40,713	636,701
1961 (3)	375,541	132,712	39,359	21,870	585,991
1962 (2)	432,791	152,768	52,455	38,327	690,258
1963 (2)	279,123	112,332	50,096	21,706	472,613
1964 (2)	307,119	119,499	72,918	22,220	526,161
1960-1964 avg.	349,057	140,328	52,245	28,967	582,345
1965 (2)	246,910	87,623	26,459	12,131	374,353
1966 (2)	313,858	146,298	36,907	15,833	524,174
1967 (2)	317,069	196,634	61,043	23,651	605,184
1968 (2)	287,971	164,493	33,548	9,605	505,963
1969 (2)	391,667	152,060	65,789	24,623	642,615
1965-1969 avg.	311,495	149,422	44,749	17,169	530,458
1970 (2)	185,111	104,668	30,975	10,870	337,202

[a]Unpublished data compiled by the late Dr. William C. Starrett, Illinois Natural History Survey.

[b]Includes species listed plus all other commercial species.

[c]Indicates rank of Alton Pool among the lower four Illinois River pools (Starved Rock, Peoria, LaGrange, and Alton) in total harvest.

exceeds the number taken from any of the upstream pools (Figure 5). The number of carp taken by electrofishing is generally equal to, or less than the number taken in upstream pools (Figure 6). As mentioned above (see Table 10), carp has been a low-priced fish in recent times (10¢ per pound wholesale, for undressed fish, in 1977 dollars), while channel catfish have been relatively high-priced (48¢ per pound wholesale for undressed fish, in 1977 dollars).

Effects of the Navigation System on the Commercial Fishery. The commercial fishery in the study reach of the Illinois River is not as productive as it was at the turn of the century, but is in considerably better condition than the fishery in the middle and upper reaches of the Illinois River. Draining and leveeing of the flood plain in the 1920's removed many backwaters and lakes which once produced the bulk of both commercial and sport species of fish. The only lakes remaining in the study reach are Meredosia Lake, and a few backwaters between river mile 66 and 78, and a few other lakes and backwaters between the mouth and river mile 15. Dam 26 at Alton increased the backwater acreage in the lower portion of the Illinois River, thereby increasing fish habitat, but we do not have quantitative data on the amount of increase.

The reduction in the quality and quantity of aquatic habitat due to sedimentation in Lake Meredosia, a U.S. Fish and Wildlife Service Refuge, has been discussed in the sedimentation section. It is possible that resuspension of bottom sediments by barge traffic in the main channel has contributed to sedimentation in the remaining lakes and backwaters in the study reach. In the reach of the river immediately above the study reach, commercially important species of fish have been affected by a die-off of the benthic organisms they feed upon. The die-off is apparently related to an upstream source of toxicity (and not to the nine-foot channel project), which is sufficiently diluted or otherwise removed from the river so that fish food organisms can survive in the study reach. Boat traffic and dredging and spoil operations may affect commercial species of fish and the organisms upon which they feed. Some commercial fishermen report that they do not fish in the main channel borders, because the currents and wave wash associated with passage of barges collapses their nets.

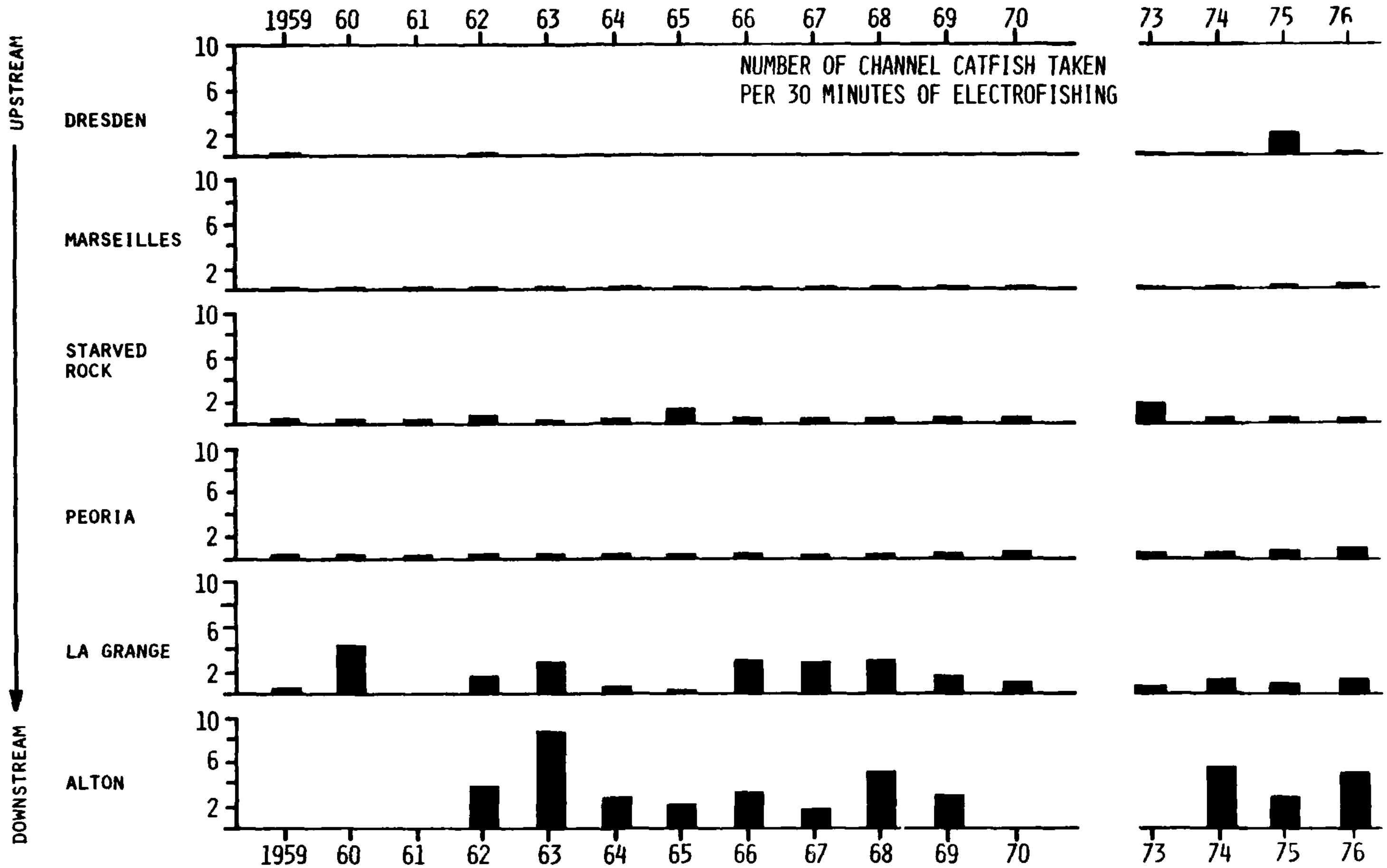


Figure 5. Number of channel catfish taken per 30 minutes of electrofishing in six pools of the Illinois Waterway from 1959 to 1976. The total number of channel catfish taken at all stations within a pool was divided by the total number of half-hour intervals fished in that pool, to obtain an average catch per unit effort for each pool. The number of electrofishing stations in each pool are: Alton (4 or 5, depending on the year), La Grange Pool (6), Peoria Pool (8), Starved Rock Pool (2), Marseilles Pool (3), and Dresden Pool (1). A small bar (heavy line) indicates that electrofishing was conducted, but few or no fish were taken, while the absence of a bar means no electrofishing was conducted.

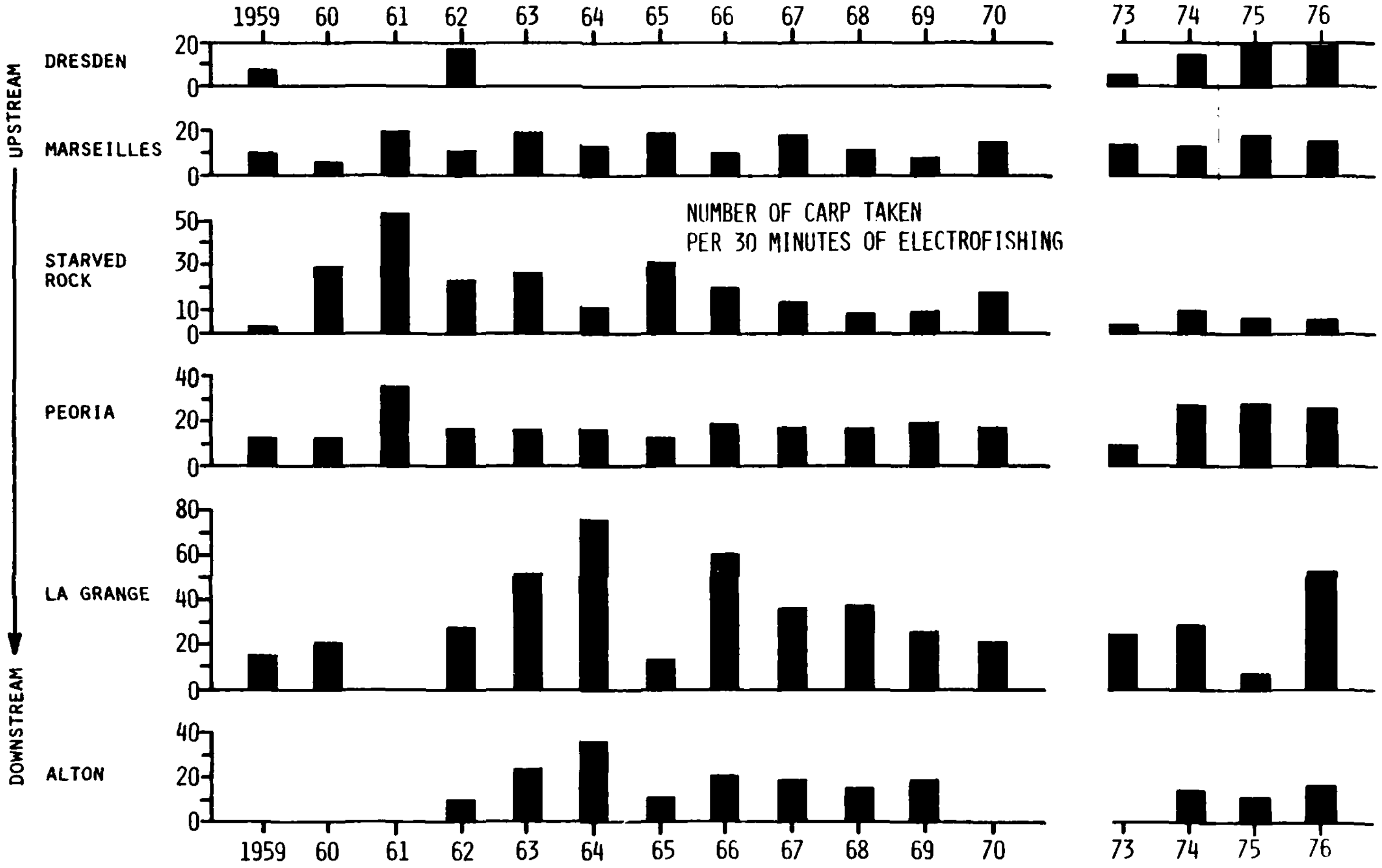


Figure 6. Number of carp taken per 30 minutes of electrofishing in six pools of the Illinois Waterway from 1959 to 1976. The total number of channel catfish taken at all stations within a pool was divided by the total number of half-hour intervals fished in that pool, to obtain an average catch per unit effort for each pool. The number of electrofishing stations in each pool are: Alton (4 or 5, depending on the year), La Grange Pool (6), Peoria Pool (8), Starved Rock Pool (2), Marseilles Pool (3), and Dresden Pool (1). A small bar (heavy line) indicates that electrofishing was conducted, but few or no fish were taken, while the absence of a bar means no electrofishing was conducted.

Commercial Fishery -- Mississippi River

A literature search for sources pertaining to the commercial fishery of the upper Mississippi River yielded several references of a quantitative nature dating from 1894 to 1976. However, fishery statistics published prior to the construction of the nine-foot navigation system (Smith, 1898; Townsend, 1902; Sette, 1925; and Fiedler, 1933) provided data only for the entire Mississippi River bordering Illinois (pools 12 through B-26, inclusive). Pre-construction data for the study area encompassed by pools 24, 25, and 26 were unavailable. For comparison with the earlier period, post-construction fishery statistics (Anderson and Peterson, 1953; Anderson and Power, 1957; Power, 1962; Lyles, 1967; and Wheeland, 1973) were used.

In addition to the above broad comparison of the pre- and post-construction commercial fishery, the following data were compiled: (1) commercial fishery statistics for pools 24, 25, and 26 for the period 1953-1976 (UMRCC, 1954-1977); (2) number of full-time and part-time Illinois commercial fishermen on the upper Mississippi River, 1950-1970 (Starrett, unpublished); and (3) a comparison of the harvest of commercial fish by Illinois fishermen from a pooled section of the Mississippi River (pools 12-26, Dubuque, Iowa to Alton, Illinois) and an unpooled section (B-26, Alton to Cairo, Illinois), 1950-1970 (Starrett, unpublished).

Subsections within the discussion of the commercial fishery deal with (1) historical aspects of the fishery; (2) changes in species composition of the commercial catch, 1894-1970; (3) recent trends in the fishery, 1950-1976; and (4) an economic evaluation of the fishery.

Historical Perspective. An excellent historical view of the commercial fishery of the upper Mississippi River is given by Carlander (1954: 57-70). It appears that an organized commercial fishery did not begin until the late 1800's. Reliable statistical records date from 1894 when the U.S. Commission of Fish and Fisheries (succeeded by the Bureau of Fisheries and Fish and Wildlife Service) began compiling quantitative

harvest data for the upper Mississippi River. By 1886, however, the commercial harvest by Iowa fishermen was of some magnitude, as described in the following account by Aldrich (1886: 10):

> Up to within a few years, the annual catch of fish from the Iowa side of the Mississippi, and from the waters of the lakes and rivers in the interior of the state, is estimated to have been not less than 4,000,000 pounds! Of this vast quantity of fish, at least 2,000,000 pounds were taken at the mouths of Iowa rivers emptying into the Mississippi and Missouri.

Illinois fishermen reported similar success in the late part of the nineteenth century, with the total annual harvest averaging about 4 million pounds between 1894-1899 (Tables 12-13). The 1906-1908 Report of the Illinois Fish Commissioners (Cohen et al., 1908: 18) stated that:

> It is encouraging to conclude, for a comparison of available statistics, that we have no reason to believe that the general fishery product of our rivers . . . /has declined/ either in value or amount . . . between 1896 and 1901.

As will be discussed in detail later, the magnitude of the upper Mississippi River commercial fishery, in both poundage and monetary value, has not changed significantly over the past eighty years, but the species composition has changed.

Pre- and Post-Construction Statistics on Harvests and Number of Fishermen, 1894-1970. Tables 12-20 show the commercial harvest of fish from the upper Mississippi River by Illinois fishermen in the pre-construction years of 1894, 1899, 1922, and 1931 and in the post-construction years of 1950, 1955, 1960, 1965, and 1970. The data indicate a somewhat stable total catch throughout the period of 3-4 million pounds. A maximum harvest of 4.3 million pounds was reported in 1899, with a minimum of 1.3 million pounds in 1931.

Although it might seem reasonable to compare the total harvest and market value of commercial fish in 1931 and 1950, the nearest pre- and

Table 12

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1894[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	37,366	1,013	7,994
Shovelnose sturgeon	40,297	1,041	8,215
Paddlefish	117,446	2,284	18,023
Bowfin	-	-	-
American eel	17,781	1,201	9,477
Mooneye[c]	4,171	103	813
Northern pike	9,685	505	3,985
Carp	235,848	5,171	40,804
Carpsuckers	-	-	-
Suckers	231,541	5,349	42,209
Buffalo	1,937,596	50,026	394,755
Catfish	806,120	36,362	286,933
Bullheads	-	-	-
White bass, yellow bass, rock bass	44,786	2,367	18,678
Sunfish[d]	16,096	460	3,630
Black bass	19,688	1,304	10,290
Crappie	19,909	817	6,447
Yellow perch	735	22	174
Walleye	17,764	1,010	7,970
Freshwater drum	421,722	10,863	85,720
Other fish	-	-	-
Mussel shells	47,500	665	5,248
Turtles	4,300	61	481
Frogs	-	-	-
Total	4,030,531	120,624	951,844
Total, fish only	3,978,551	119,898	946,115
Number of full-time fishermen		-	
Number of part-time fishermen		-	
Total fishermen		771	

[a]Smith, 1898.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

Table 13

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1899[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	30,794	1,094	7,926
Shovelnose sturgeon	104,644	2,155	15,613
Paddlefish	148,216	4,171	30,219
Bowfin	-	-	-
American eel	16,050	937	6,789
Mooneye[c]	1,805	59	427
Northern pike	5,475	309	2,239
Carp	1,446,698	27,983	202,737
Carpsuckers	-	-	-
Suckers	125,610	3,416	24,749
Buffalo	1,576,998	40,544	293,741
Catfish	468,403	24,919	180,538
Bullheads	-	-	-
White bass, yellow bass, rock bass	10,797	533	3,862
Sunfish[d]	33,641	1,029	7,455
Black bass	18,744	1,250	9,056
Crappie	57,044	2,343	16,975
Yellow perch	1,521	55	398
Walleye	15,040	890	6,448
Freshwater drum	253,696	6,532	47,324
Other fish	12,410	59	427
Mussel shells	8,910,000	43,468	314,926
Turtles	129,735	2,373	17,192
Frogs	4,422	536	3,883
Total	13,371,923	164,655	1,192,925
Total, fish only	4,327,766	118,278	856,924
Number of full-time fishermen		-	
Number of part-time fishermen		-	
Total fishermen		1,149	

[a]Townsend, 1902.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

Table 14

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1922[a]

Species	Pounds	Value, $	1977$[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	56,000	4,380	17,108
Paddlefish	40,500	3,545	13,847
Bowfin	5,100	254	992
American eel	4,000	215	840
Mooneye[c]	-	-	-
Northern pike	-	-	-
Carp	1,105,525	61,637	240,754
Carpsuckers	-	-	-
Suckers	28,300	1,972	7,703
Buffalo	584,675	53,959	210,764
Catfish	385,955[e]	45,479	177,641
Bullheads	-	-	-
White bass, yellow bass, rock bass	6,300	486	1,898
Sunfish[d]	11,200	960	3,750
Black bass	4,800	480	1,875
Crappie	15,575	1,327	5,183
Yellow perch	4,000	320	1,250
Walleye	500	25	98
Freshwater drum	293,550	23,330	91,127
Other fish	7,000	410	1,601
Mussel shells	468,000	11,436	44,669
Turtles	12,000	40	156
Frogs	-	-	-
Total	3,033,524	212,574	830,314
Total, fish only	2,553,524	201,098	785,489
Number of full-time fishermen		-	
Number of part-time fishermen		-	
Total fishermen		688	

[a]Sette, 1925.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Includes bullheads.

Table 15

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1931[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	25,366	2,680	13,893
Paddlefish	23,485	2,095	10,860
Bowfin	-	-	-
American eel	835	44	228
Mooneye[c]	1,000	20	104
Northern pike	-	-	-
Carp	562,999	20,350	105,494
Carpsuckers	2,900	122	632
Suckers	7,255	310	1,607
Buffalo	252,632	16,016	83,027
Catfish	296,374[e]	31,882	165,276
Bullheads	-	-	-
White bass, yellow bass, rock bass	100	15	78
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	-	-	-
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	105,982	6,369	33,017
Other fish	-	-	-
Mussel shells	1,238,566	10,167	52,706
Turtles	250	8	41
Frogs	-	-	-
Total	2,517,744	92,527	479,660
Total, fish only	1,278,928	82,352	426,913
Number of full-time fishermen		196	
Number of part-time fishermen		234	
Total fishermen		430	

[a]Fiedler, 1933.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Includes bullheads.

Table 16

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1950[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	2,800	626	1,492
Paddlefish	41,800	7,504	17,882
Bowfin	900	45	107
American eel	600	92	219
Mooneye[c]	200	4	10
Northern pike	-	-	-
Carp	1,016,300	52,635	125,429
Carpsuckers	15,800	427	1,018
Suckers	7,000	301	717
Buffalo	1,054,600	111,951	266,779
Catfish	398,300	93,811	223,552
Bullheads	18,200	3,532	8,417
White bass, yellow bass, rock bass	-	-	-
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	-	-	-
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	366,500	37,607	89,617
Other fish	-	-	-
Mussel shells	-	-	-
Turtles	-	-	-
Frogs	-	-	-
Total	2,923,000	308,535	735,239
Total, fish only	2,923,000	308,535	735,239
Number of full-time fishermen		122	
Number of part-time fishermen		126	
Total fishermen		248	

[a]Anderson and Peterson, 1953.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

Table 17

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1955[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	51,600	9,288	20,620
Paddlefish	122,600	13,278	29,477
Bowfin	900	27	60
American eel	1,000	80	178
Mooneye[c]	400	16	36
Northern pike	-	-	-
Carp	1,458,600	58,336	129,506
Carpsuckers	43,700	2,185	4,851
Suckers	800	24	53
Buffalo	1,043,200	93,888	208,431
Catfish	628,700[e]	150,888	334,971
Bullheads	-	-	-
White bass, yellow bass, rock bass	-	-	-
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	10,000	1,803	4,003
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	531,300	37,191	82,564
Other fish	-	-	-
Mussel shells	-	-	-
Turtles	-	-	-
Frogs	-	-	-
Total	3,892,800	367,004	814,749
Total, fish only	3,892,800	367,004	814,749
Number of full-time fishermen		125	
Number of part-time fishermen		182	
Total fishermen		307[f]	

[a]Anderson and Power, 1957.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Includes bullheads.

[f]Starrett, unpublished.

Table 18

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1960[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	4,700	568	1,167
Paddlefish	29,100	3,579	7,351
Bowfin	7,600	228	468
American eel	-	-	-
Mooneye[c]	-	-	-
Northern pike	-	-	-
Carp	1,516,000	72,768	149,465
Carpsuckers	38,900	1,945	3,995
Suckers	2,500	125	257
Buffalo	1,482,200	144,810	297,440
Catfish	601,000	150,250	308,614
Bullheads	33,200	5,743	11,796
White bass, yellow bass, rock bass	-	-	-
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	28,800	5,184	10,648
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	475,500	38,040	78,134
Other fish	5,200[e]	260	534
Mussel shells	-	-	-
Turtles	-	-	-
Frogs	-	-	-
Total	4,224,700	423,500	869,869
Total, fish only	4,224,700	423,500	869,869
Number of full-time fishermen		118	
Number of part-time fishermen		177	
Total fishermen		295[f]	

[a]Power, 1962.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Gars.

[f]Starrett, unpublished.

Table 19

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1965[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	10,700	2,238	4,516
Paddlefish	59,700	6,488	13,093
Bowfin	700	40	81
American eel	600	86	174
Mooneye[c]	1,100	52	105
Northern pike	-	-	-
Carp	1,314,500	63,920	128,991
Carpsuckers	17,900	1,061	2,141
Suckers	1,600	60	121
Buffalo	980,200	99,385	200,559
Catfish	645,800[e]	164,920	332,809
Bullheads	-	-	-
White bass, yellow bass, rock bass	-	-	-
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	-	-	-
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	430,400	32,125	64,828
Other fish	7,100[f]	273	551
Mussel shells	218,200	7,126	14,380
Turtles	5,300	1,054	2,127
Frogs	-	-	-
Total	3,693,800	378,828	764,475
Total, fish only	3,470,300	370,648	747,968
Number of full-time fishermen		78	
Number of part-time fishermen		163	
Total fishermen		241[g]	

[a]Lyles, 1967.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Includes bullheads.

[f]Gars.

[g]Starrett, unpublished.

Table 20

The Commercial Harvest of Fish, Mussels, Turtles, and Frogs from the Mississippi River Bordering Illinois by Illinois Fishermen and Number of Mississippi River Commercial Fishermen Licensed in Illinois in 1970[a]

Species	Pounds	Value, $	1977 $[b]
Lake sturgeon	-	-	-
Shovelnose sturgeon	18,100	4,387	7,743
Paddlefish	89,000	10,696	18,878
Bowfin	800	38	67
American eel	100	20	35
Mooneye[c]	-	-	-
Northern pike	-	-	-
Carp	1,078,200	52,893	93,356
Carpsuckers	43,200	2,504	4,420
Suckers	400	22	39
Buffalo	1,096,200	147,032	259,511
Catfish	431,100[e]	138,357	244,200
Bullheads	-	-	-
White bass, yellow bass, rock bass	-	-	-
Sunfish[d]	-	-	-
Black bass	-	-	-
Crappie	-	-	-
Yellow perch	-	-	-
Walleye	-	-	-
Freshwater drum	409,800	33,300	58,775
Other fish	9,000[f]	355	627
Mussel shells	-	-	-
Turtles	-	-	-
Frogs	-	-	-
Total	3,177,900	389,705	687,829
Total, fish only	3,177,900	389,705	687,829
Number of full-time fishermen		59	
Number of part-time fishermen		93	
Total fishermen		152[g]	

[a]Wheeland, 1973.

[b]Conversion factors given in Table 21.

[c]Includes goldeye.

[d]Bluegill and green sunfish.

[e]Includes bullheads.

[f]Gars.

[g]Starrett, unpublished.

post-construction years, the fish populations had been reduced to exceptionally low levels in 1931 as a result of successive drouths in 1929, 1930, and 1931 (Department of Registration and Education, 1931: 25 and 1932: 33). Consequently, we decided to use the year 1922 as the pre-construction year.

The total harvest of 2.9 million pounds of fish in 1950 was greater than the harvest of 2.5 million pounds in 1922, and 1.3 million in 1931.

Tables 12-20 also show the market value of the commercial catch. All monetary values were converted to 1977 dollars by using conversion factors given in Table 21. The corrected values for 1894-1970 show that a relatively stable amount of about $600,000-900,000 of fish per year were harvested by Illinois fishermen from the upper Mississippi River. The highest value of the fishery was reported in 1894 at $946,000, whereas the lowest value was in 1931 at $427,000. The market value decreased by 6 percent, from $785,489 prior to construction of the navigation system in 1922 to $735,000 following construction in 1950.

The total number of Illinois commercial fishermen engaged in the upper Mississippi River fishery fell from a high of 1,149 in 1899 to only 152 in 1970 (Tables 13-20). It can be seen that since 1931, the greatest number of fishermen have been employed on a part-time basis.

Changes in Species Composition, 1894-1970. In preparing Tables 12-20 it was apparent that major changes had taken place in the species composition of the commercial harvest from the upper Mississippi River. For ease of discussion of these changes, the following fish groupings were used: sturgeons, paddlefish, American eel, carp, suckers and carpsuckers, buffalo, catfish and bullheads, freshwater drum, and other fish. At this point, only historical quantitative changes are outlined. A discussion of these changes as related to the navigation system follows in a separate section.

Sturgeons: The lake sturgeon (*Acipenser fulvescens*) was included in the commercial harvests of 1894 and 1899, when 37,000 and 31,000 pounds were taken, respectively. No lake sturgeon were reported in the 1922-1970 statistics.

Table 21

Factors for Converting 1890-1976 Dollars to July 1977 Dollars

Multiply dollars from any given year times the factor for that year. The result is July 1977 dollars.

1890	6.744	1912	5.745	1934	5.059	1956	2.149
1891	6.767	1913	5.414	1935	4.719	1957	2.089
1892	7.245	1914	5.537	1936	4.674	1958	2.060
1893	7.087	1915	5.444	1937	4.380	1959	2.056
1894	7.891	1916	4.420	1938	4.812		
1895	7.734	1917	3.216	1939	4.897	1960	2.054
1896	8.155	1918	2.883			1961	2.062
1897	8.121	1919	2.730	1940	4.812	1962	2.056
1898	7.796			1941	4.322	1963	2.062
1899	7.245	1920	2.448	1942	3.829	1964	2.058
		1921	3.875	1943	3.657	1965	2.018
1900	6.744	1922	3.906	1944	3.636	1966	1.953
1901	6.839	1923	3.755	1945	3.570	1964	1.949
1902	6.411	1924	3.859	1946	3.128	1968	1.901
1903	6.349	1925	3.657	1947	2.548	1969	1.830
1904	6.328	9126	3.777	1948	2.354		
1905	6.287	1927	3.953	1949	2.476	1970	1.765
1906	6.091	1928	2.898			1971	1.711
1907	5.801	1929	3.969	1950	2.383	1972	1.638
1908	6.015			1951	2.139	1973	1.450
1909	5.585	1930	4.370	1952	2.200	1974	1.218
		1931	5.184	1953	2.230	1975	1.115
1910	5.354	1932	5.801	1954	2.225	1976	1.064
1911	5.818	1933	5.732	1955	2.220	1977	1.000 (July)

Sources: Newspaper Enterprise Association. 1977. The world almanac and book of facts. "Purchasing power of the dollar." Page 48.

U.S. Department of Commerce Bureau of the Census. 1975. Historical statistics of the U.S. -- colonial times to 1970. Bicentennial Edition. Part 1. Series E-23. Page 199.

Method: U.S. Department of Commerce (1975) gives wholesale price indices for all commodities 1890-1970. (Note: consumer price indices are not the same.) Newspaper Enterprise Association (1977) gives the same data expressed as a reciprocal divided by 100. If 1967 is 100.0, the July 1977 index is 194.9. The factor for each year was obtained by dividing 194.9 by the wholesale price index for that year. E.g., for 1950, 194.9 divided by 81.8 = 2.383.

The maximum harvest of shovelnose sturgeon (Scaphirhynchus platorhynchus) was 105,000 pounds in 1899. By 1922, preceding construction of the navigation channel, the annual catch of this species had fallen to 56,000 pounds. The 1950-1970 average harvest of shovelnose sturgeon was only 17,500 pounds.

Paddlefish: In 1894 and 1899, the paddlefish (Polyodon spathula) catch comprised about 3 percent of the total harvest. Paddlefish poundage fell from a high of 148,000 pounds in 1899 to 40,500 pounds by 1922. The average harvest of this species between 1950 and 1970 was about 68,500 pounds, representing about 2 percent of the total catch.

American eel: American eel (Anguilla rostrata) harvest averaged 17,000 pounds in 1894-1899. The data show a steady decline in eel catch from 1899-1970, with only 100 pounds reported in 1970.

Carp: Carp (Cyprinus carpio) comprised only 6 percent of total fish catch in 1894. By 1899, however, a carp harvest of 1.5 million pounds represented 33 percent of the catch. Between 1899-1970, carp poundage averaged 1.2 million pounds and continued to comprise about one-third of the total annual harvest. Carp replaced the buffalo (Ictiobus spp.) as the most abundant commercial species between 1899 and 1922. The following are carp : buffalo ratios for specified years: 1894, 1:8; 1899, 1:1; and 1922, 2:1.

Carpsuckers and suckers: Carpsuckers (Carpiodes spp.) were not reported in the commercial statistics between 1894-1922. Three thousand pounds were taken in 1931 (a drought year) prior to construction of the navigation system. Post-construction statistics show an average annual harvest of about 32,000 pounds between 1950 and 1970.

Suckers (probably white sucker, Catastomus commersoni; blue sucker, Cycleptus elongatus; northern hog sucker, Hypentelium nigricans; and redhorses, Moxostoma spp.) constituted one of the most abundant groups of fish taken in 1894 and 1899, averaging 179,500 pounds for those years. However, the catch of this group fell steadily between 1899 and 1970. Only 400 pounds of suckers were taken in 1970.

Buffalo: In 1894, buffalo (Ictiobus spp.) constituted 49 percent of the upper Mississippi River catch by Illinois fishermen. The buffalo

harvest fell from 1.9 million pounds in 1894 to 585,000 pounds in 1922. Following construction of the navigation system, the annual buffalo harvest averaged about 1 million pounds and about one-third of the total catch. Carp : buffalo ratios for selected years are given above.

Catfish and bullheads: Catfish and bullheads (Ictalurus spp.) totalling 806,000 pounds constituted 20 percent of the harvest in 1894. From 1899-1970, catches of this group fluctuated between 300,000-600,000 pounds annually. Catfish and bullheads composed 10-20 percent of the catch during this period with no apparent trends.

Freshwater drum: Catches of freshwater drum (Aplodinotus grunniens) were 294,000 pounds in 1922 and 366,000 pounds in 1950. Pre-construction data indicated a downward trend in the harvest of this species from 1894 to 1931. The post-construction catches from 1950 to 1970 averaged 443,000 pounds annually. No trends were apparent during this latter period.

Other fish: At various times in the past, sport fishermen would lobby to have fishing regulations established which prohibited commercial fishermen from taking game species. A blank in Tables 10-18 could mean either that less than 100 lbs. of a particular species was taken that year, or that commercial fishermen were prohibited from taking the species. Whenever possible, we have tried to separate the effects of changes in regulations from the effects of changes in fish populations, in determining the reasons for fluctuations in commercial harvests.

Northern pike (Esox lucius) harvests of 9,700 and 5,500 pounds were reported in 1894 and 1899, respectively. No pike were reported in the 1922-1970 period. Pike probably were always more common in the northern parts of the upper Mississippi River and the Illinois River than in the project area. In addition, commercial fishermen were prohibited from taking pike in the later years.

A composite poundage for white bass (Morone chrysops), yellow bass (Morone mississippiensis), and rock bass (Ambloplites rupestris) showed

a steady decline from 45,000 pounds in 1894 to only 100 pounds in 1931. None of these species were reported in the post-construction years, 1950-1970, when regulations prohibited commercial fishermen from taking these fish.

Commercial harvest of sunfish (Lepomis spp.) and black bass (Micropterus spp.) was similarly prohibited in the post-construction years.

Crappie (Pomoxis spp.) harvests of 20,000, 50,000, and 16,000 pounds were reported in 1894, 1899, and 1922, respectively. Regulations prohibited taking of crappie commercially until the 1950's, when Tables 15 and 16 show 10,000 and 29,000 pounds were caught in 1955 and 1960 respectively. Commercial harvest of crappie has been prohibited again in more recent years.

Yellow perch (Perca flavescens) and walleye (Stizostedion vitreum) constituted a small percentage of the total harvest from 1894-1922. Regulations prohibit the commercial harvest of walleye. Yellow perch have probably been eliminated due to habitat changes, but were never very abundant in the study area because they have a northern distribution.

Recent Trends in the Commercial Fishery. To determine post-construction trends in the upper Mississippi River commercial fishery, two sets of data (Starrett, unpublished and UMRCC, 1954-1976) for the period 1950-1976 were examined. Starrett compiled total harvest records from a pooled section of the river (pools 12-26) and an unpooled section (B-26, Alton to Cairo, Illinois) between 1950 and 1970 (Table 22). Also included in the unpublished files of this investigator's data were the numbers of full-time and part-time Illinois commercial fishermen engaged on the upper Mississippi River, 1950-1970 (Table 23). Data compiled by the Upper Mississippi River Conservation Committee (UMRCC) from 1953 to 1976 provided harvest records of carp, buffalo, channel catfish, freshwater drum, and all commercial species for individual pools 24, 25, and 26 (Tables 24-26).

Table 22 shows that, with the exception of the catches in 1951 and 1952, pools 12-26 consistently yielded 2-4 million pounds of fish from 1950 to 1970. The catch from the unpooled section, however, fluctuated

Table 22

A Comparison of the Fish Harvest (in Pounds) by Illinois Commercial Fishermen from a Pooled Section of the Mississippi River (Pools 12-26) and an Unpooled Section (Alton to Cairo, Illinois), 1950-1970

Year	Pooled Section, Lbs. (% of harvest)		Unpooled Section, Lbs. (% of harvest)		Total Both Sections
1950	2,618,646	(94)	169,427	(6)	2,788,073
1951	695,460	(96)	32,498	(4)	727,958
1952	798,387	(92)	65,870	(8)	864,257
1953	2,543,485	(97)	75,073	(3)	2,618,558
1954	2,609,208	(99)	30,166	(1)	2,639,374
1955	3,589,008	(99)	49,574	(1)	3,638,582
1950-1955 avg.	2,142,366		70,435		2,212,800
1956	3,284,909	(99)	25,255	(1)	3,310,164
1957	3,165,893	(99)	31,070	(1)	3,196,963
1958	3,846,020	(97)	118,680	(3)	3,964,700
1959	4,176,390	(99)	39,180	(1)	4,215,570
1960	4,058,141	(99)	12,148	(1)	4,070,289
1955-1960 avg.	3,706,271		45,267		3,751,537
1961	2,866,097	(99)	13,950	(1)	2,880,047
1962	2,486,401	(99)	9,863	(1)	2,496,264
1963	3,270,446	(92)	269,220	(8)	3,539,666
1964	3,103,346	(96)	134,077	(4)	3,237,423
1965	3,389,774	(98)	80,562	(2)	3,470,336
1961-1965 avg.	3,023,213		101,534		3,124,747
1966	3,266,417	(95)	188,151	(5)	3,454,568
1967	2,937,559	(97)	87,578	(3)	3,025,137
1968	2,612,510	(98)	57,639	(2)	2,670,149
1969	2,809,554	(97)	79,696	(3)	2,889,250
1970	3,055,161	(96)	122,739	(4)	3,177,900
1966-1970 avg.	2,936,240		107,161		3,043,401

Table 23

Reported Number of Full-Time and Part-Time Illinois Commercial Fishermen Actively Engaged in River Fishing on the Illinois, Mississippi, and All Illinois Rivers, 1950-1970[a]

Year	Illinois River			Mississippi River			All Illinois Rivers		
	FT[b]	PT[c]	Total	FT	PT	Total	FT	PT	Total
1950	106	169	275	122	126	248	253	442	695
1951	57	116	173	77	152	229	148	370	518
1952	57	71	128	41	66	107	105	181	286
1953	133	221	354	120	186	306	277	517	794
1954	111	134	245	135	175	310	261	371	632
1955	96	176	272	125	182	307	228	416	644
1950-1955 avg.	93	148	241	103	148	251	212	383	595
1956	88	103	191	130	167	297	230	323	553
1957	105	100	205	133	175	308	255	322	577
1958	70	142	212	131	219	350	212	423	635
1959	61	118	179	137	183	320	205	352	557
1960	69	73	142	118	177	295	189	319	508
1956-1960 avg.	79	107	186	130	184	314	218	348	566
1961	65	76	141	115	170	285	185	301	486
1962	50	88	138	98	158	256	151	302	453
1963	48	76	125	76	156	232	125	293	418
1964	56	59	115	62	167	229	121	275	396
1965	44	90	134	78	163	241	126	303	429
1961-1965 avg.	53	78	131	86	163	249	142	295	437
1966	23	74	97	80	169	249	110	299	409
1967	43	72	115	75	123	198	122	229	351
1968	38	63	101	56	117	173	97	216	313
1969	30	59	89	48	106	154	86	203	289
1970	22	46	68	59	93	152	84	176	260
1966-1970 avg.	31	63	94	64	122	186	100	225	325

[a]Includes only those fishermen who had purchased tags or licenses for five or more nets. Source: Starrett, unpublished.

[b]Full-time.

[c]Part-time.

Table 24

Yearly Total and 5-Year Average Harvest (in Pounds) of Carp, Buffalo, Channel Catfish, Freshwater Drum, and All Commercial Species from Pool 24, Mississippi River, 1953-1976[a]

Year	Carp	Buffalo	Channel Catfish	Freshwater Drum	Total[b]
1953	45,918	39,224	20,009	16,845	130,763
1954	68,428	59,374	50,196	53,253	242,793
1955	102,951	89,026	38,015	63,785	302,221
1956	70,597	79,896	43,472	51,112	257,139
1957	70,890	93,457	57,729	50,003	280,813
1953-1957 avg. (14)[c]	71,757	72,195	41,884	47,000	242,746
1958	57,166	39,148	48,821	26,037	181,861
1959	88,612	51,303	50,864	40,521	248,593
1960	70,053	48,080	41,384	17,419	185,385
1961	89,839	42,518	45,970	39,067	230,594
1962	121,788	52,338	35,780	26,672	244,421
1958-1962 avg. (18)	85,492	46,655	44,564	29,943	218,171
1963	345,990	61,957	66,474	69,291	569,893
1964	149,712	60,100	95,780	50,933	368,101
1965	218,881	68,664	79,951	66,461	445,482
1966	92,241	27,542	72,415	64,727	278,183
1967	134,082	34,787	60,357	49,329	298,652
1963-1967 avg. (11)	188,181	50,610	74,995	60,148	392,062
1968	43,745	42,652	30,117	16,275	142,759
1969	108,417	94,507	38,366	69,173	331,089
1970	65,061	34,609	13,415	40,943	170,125
1971	37,213	40,564	17,957	29,080	137,328
1972	89,155	40,084	21,880	43,031	214,530
1968-1972 avg. (19)	68,718	50,483	24,347	39,700	199,166
1973	82,817	39,560	18,760	74,793	225,146
1974	293,282	53,372	34,408	58,469	446,890
1975	118,898	26,833	18,651	16,028	197,890
1976	61,859	27,727	8,483	5,130	107,163
1973-1976[d] avg. (16)	139,214	36,873	20,076	38,605	244,272

[a]Data compiled by the Upper Mississippi River Conservation Committee.

[b]Includes species listed plus all other commercial species.

[c]Indicates the rank of Pool 24 among all 26 Mississippi River pools in total harvest.

[d]1977 data unavailable.

AD-A115 985 ILLINOIS NATURAL HISTORY SURVEY HAVANA RIVER RESEARCH LAB F/G 6/6
FISH AND WILDLIFE HABITAT CHANGES RESULTING FROM CONSTRUCTION O--ETC(U)
APR 79 R E SPARKS, F C BELLROSE, F L PAVEGLIO

UNCLASSIFIED NL

2 OF 3
AD A
115 985

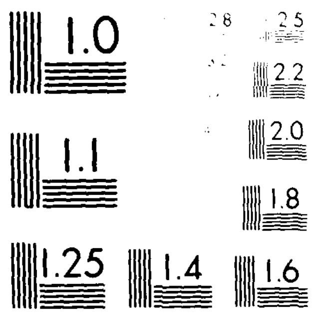

1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Table 25

Yearly Total and 5-Year Average Harvest (in Pounds) of Carp, Buffalo, Channel Catfish, Freshwater Drum, and All Commercial Species from Pool 25, Mississippi River, 1953-1976[a]

Year	Carp	Buffalo	Channel Catfish	Freshwater Drum	Total[b]
1953	100,774	53,985	43,421	87,444	328,905
1954	67,811	40,788	56,478	59,983	245,972
1955	154,203	114,116	85,578	54,145	427,515
1956	121,635	81,351	57,447	51,576	335,800
1957	96,631	76,543	99,726	77,669	385,178
1953-1957 avg. (8)[c]	108,211	73,357	68,530	66,163	344,674
1958	105,209	89,391	118,316	104,037	446,556
1959	94,085	75,425	47,910	64,102	287,252
1960	117,304	133,189	67,267	85,012	422,851
1961	117,567	86,465	58,855	75,065	357,160
1962	98,894	60,783	60,652	57,265	293,136
1958-1962 avg. (13)	106,612	89,051	70,600	77,096	361,391
1963	130,089	59,718	74,998	56,229	327,540
1964	172,443	116,983	92,451	97,014	494,351
1965	173,966	82,471	69,619	72,472	406,146
1966	168,485	117,791	60,724	94,325	448,086
1967	170,988	99,644	80,608	117,099	477,408
1963-1967 avg. (10)	163,194	95,321	75,680	87,428	430,706
1968	153,205	78,386	62,639	41,723	348,616
1969	157,060	137,024	63,628	38,347	402,735
1970	171,102	117,966	52,592	78,649	435,531
1971	138,398	110,364	36,185	52,072	344,483
1972	145,037	109,839	33,806	37,095	336,105
1968-1972 avg. (10)	152,960	110,716	49,570	49,577	373,494
1973	215,535	92,010	42,684	52,559	415,216
1974	174,212	118,458	32,406	37,806	374,169
1975	202,323	138,927	30,338	42,190	429,236
1976	215,834	104,306	45,003	21,517	406,952
1973-1976[d] avg. (10)	201,976	113,425	37,608	38,518	406,393

[a]Data compiled by the Upper Mississippi River Conservation Committee.

[b]Includes species listed plus all other commercial species.

[c]Indicates rank of Pool 25 among all 26 Mississippi River pools in total harvest.

[d]1977 data unavailable.

Table 26

Yearly Total and 5-Year Average Harvest (in Pounds) of Carp, Buffalo, Channel Catfish, Freshwater Drum, and All Commercial Species from Pool 26, Mississippi River, 1953-1976[a]

Year	Carp	Buffalo	Channel Catfish	Freshwater Drum	Total[b]
1953	74,871	62,095	27,460	26,903	219,861
1954	136,647	174,092	56,224	73,735	493,986
1955	218,021	167,008	70,638	78,670	582,053
1956	80,452	60,849	46,099	39,460	232,476
1957	69,226	95,506	116,021	61,663	358,492
1953-1957 avg. (7)[c]	115,843	112,110	63,288	56,086	377,374
1958	151,494	101,118	99,452	46,411	405,600
1959	226,189	100,570	82,391	86,178	502,478
1960	336,906	66,076	75,501	49,134	543,231
1961	70,116	56,892	70,024	23,996	238,606
1962	51,160	54,759	74,119	15,627	209,838
1958-1962 avg. (12)	167,173	75,883	80,297	44,269	379,951
1963	85,303	68,970	59,669	24,040	242,656
1964	188,543	154,894	117,109	23,125	495,704
1965	237,519	123,489	77,783	13,645	464,003
1966	57,454	74,447	73,380	18,898	256,163
1967	76,490	82,303	67,662	15,038	256,184
1963-1967 avg. (13)	129,062	100,821	79,121	18,949	342,942
1968	133,565	67,628	103,647	18,933	342,505
1969	99,731	107,729	97,260	17,197	338,012
1970	167,450	128,343	90,970	16,484	411,544
1971	51,065	88,210	33,411	7,330	180,016
1972	183,975	78,676	29,312	45,062	353,487
1968-1972 avg. (13)	127,157	94,117	70,920	21,001	325,113
1973	42,673	41,868	22,727	3,780	115,477
1974	107,063	104,208	59,043	10,007	293,752
1975	400,859	232,501	55,506	28,185	753,537
1976	175,807	144,034	75,233	27,015	506,607
1973-1976[d] avg. (9)	181,601	130,653	53,127	17,247	417,343

[a]Data compiled by the Upper Mississippi River Conservation Committee.

[b]Includes species listed plus all other commercial species.

[c]Indicates rank of Pool 26 among all 26 Mississippi River pools in total harvest.

[d]1977 data unavailable.

between 9,900 and 269,000 pounds during this period. Note that although the pooled section represented more river mileage (380 miles) than the unpooled section (203 miles), harvest from the unpooled section was disproportionately smaller, with the pooled section comprising 92-99 percent of the total catch. The reduced harvest in the lower unpooled section was most likely due to industrial and municipal pollutants entering the river in the St. Louis area (Barnickol and Starrett, 1951: 275). Other factors influencing the fishery of the Mississippi River below Lock and Dam 26 were increased turbidity brought about by entrance of the Missouri River and lack of suitable backwaters and sloughs for fish spawning due to extensive levee and drainage systems (Barnickol and Starrett, 1951: 274). Due to these reasons, it is not advisable to use Table 22 for a strict comparison of pooled vs. unpooled harvests, for, indeed, both river sections have been altered by man's activities. The data are presented only to provide a recent history of fish harvest.

The number of commercial fishermen engaged in the upper Mississippi River fishery steadily declined between 1950 and 1970 (Table 23). There appeared to be a general increase in the total number of fishermen from 1950 to 1958, when 350 fishermen were employed. There were only 152 fishermen in 1970. The percentage composition of full-time vs. part-time fishermen also changed during the period. Between 1950 and 1960, an average of 41 percent of the total fishermen were reported as full-time. Only 34 percent were engaged full-time in the 1961-1970 period.

Table 24 shows the harvest of commercial species from Pool 24 from 1953 to 1976. Although the total harvest did not change significantly during the period, as indicated by the five-year averages, the data show increases in the catch of carp and decreases of buffalo and channel catfish. In addition, the ratio of carp catch to that of buffalo increased from 1:1 in the 1953-1957 period to 4:1, 1973-1976. Pool 24 yielded an average annual harvest of about 260,000 pounds of all commercial fish and had an average rank of 16 among the 26 upper Mississippi River navigation pools, 1953-1976.

Pool 25 produced an annual average of about 383,000 pounds for the 24-year period, 1953-1976 (Table 25). Carp catch increased twofold during the period, with the annual harvest increasing from 108,000 pounds, 1953-1956, to 202,000 pounds, 1973-1976. Buffalo poundage also increased,

climbing from a low of 41,000 pounds in 1954 to 139,000 pounds in 1975. Both channel catfish and freshwater drum harvests decreased equally, with catches of each species declining from about 75,000 pounds per year from 1953-1967 to only 44,000 pounds between 1968 and 1976. Pool 25 had an average ranking of 10th of the 26 pools, 1953-1976.

Pool 26 harvests and trends resembled those of Pool 25 (Table 26). The pool ranked 11th during the 24-year period, 1953-1976, and had an average annual catch of about 370,000 pounds. As in Pool 25, carp and buffalo harvests increased, while those of channel catfish and freshwater drum decreased.

A comparison of all 3 pools (24, 25, and 26) in the study area indicated that the total harvest of commercial fish remained relatively constant in the period 1953-1976. However, changes in the species composition were apparent. Carp and buffalo catches increased, while those of channel catfish and freshwater drum decreased.

<u>Economic Factors Affecting the Commercial Fishery</u>. The magnitude of the commercial fishery at the turn of the century can best be described by the following excerpt from Cohen et al. (1908: 16):

> The river fisheries of Illinois gave employment in 1899 to 2,389 men, and utilized a capital of $225,000. Sixteen steamboats, 200 house-boats and 1,500 row-boats were used in these fisheries, together with about 45 miles of seines, 10 miles of trammel nets, half a mile of gill-nets, and 14,000 fyke-nets, pound-nets and traps. . . . Illinois furnishes, indeed, more than one-third of the fishes sent to market from all the streams of the Mississippi valley — valued in 1899 at $1,473,000. . . . The Great Lakes fisheries in Illinois waters are of insignificant proportions. The total longshore product for Cook and Lake Counties was $12,500 — about $2,000 less than the sum derived from our river turtles alone.

The importance of this tremendous fishery to the economy of river communities from 1890 to 1940 was outlined by Taylor (1951: 402-404, as quoted in Carlander, 1954: 69):

The population of the mid-west grew to great proportions, and villages grew to cities at a time when ocean fisheries had little access to the market. A taste was established for small-sized freshwater fish of the lakes and rivers. . . . In response to insistent demand, prices rose disproportionately to the diminishing supply so that the Great Lakes and Mississippi River system experienced the greatest rise in price of all the regions of the country, and is the only region of the country to have a higher average price for its fish in terms of purchasing power in the 1921-1940 period than in the pre-1908 period. The percentage improvement in income in dollars of constant purchasing power per fisherman exceeds that of any other region.

Following World War II, with the development of improved methods of fish preservation and transportation, the marine fisheries began to compete more directly with river fisheries (Carlander, 1954: 49). At the same time, there appeared to be a change in taste and popularity of various fishery products. This was particularly apparent to the Jewish community, as Carlander (1954: 48) noted:

The Jewish people have always been the principal purchasers of carp shipped to the eastern markets. "Gefilite" fish, prepared from carp is a particular delicacy but its preparation takes quite a bit of time which modern housewives do not care to spend.

The inconvenience to modern Jewish housewives of preparing Gefilite led to the manufacture of a Gefilite fish product by fish food companies on the east coast, with carp being the major constituent. However, Starrett (unpublished) found that by 1960 the use of carp even in manufactured Gefilite was diminishing as shown in the following correspondence received by Dr. Starrett from Rubasch and Sons, Inc., a fish food processor in New Jersey:

In reply to your letter of March 23, 1960, we would like to state that a considerable proportion of our Gefilite fish pack is now made without carp.

In a survey of New York and Boston fish markets in 1960, Dr. Starrett found that the wholesale freshwater fish business on the East Coast was declining (Starrett, unpublished). Starrett noted that of the 21 freshwater fish dealers in New York prior to World War II, only 11 remained in 1960. Only one major handler of freshwater fish was found in Boston. Starrett listed reasons for the decline as (1) preservation and transportation costs of freshwater fish were too high, (2) freshwater fish businesses were being absorbed by the saltwater markets, and (3) the jarred Gefilte fish business reduced the demand for fresh fish.

The expanding marine fishery had an effect on freshwater fish sales even in the vicinity of the Mississippi and Illinois Rivers. In a statewide survey of 271 Illinois retail grocery stores in 1960, Starrett (unpublished) found that 182 (67%) did not sell fresh fish. The main objections given to handling fresh Illinois fish were: (1) 46 (17%) stores said they would not sell, (2) 93 (29%) said fresh fish would not keep, (3) 120 (34%) said they were not packaged, (4) 61 (22%) said there was no source of supply, and (5) 23 (6%) said they objected to buying a license. Of the retail stores interviewed, 209 (77%) said there were very few customer requests for fresh fish.

The effect these changes had on the wholesale prices paid to Mississippi River commercial fishermen is shown in Table 22. In terms of 1977 dollars, prices changed as follows: carp, down 13¢ a lb. from a peak of 22¢ in 1922; buffalo down 12¢ from a peak of 30¢ in 1922; channel catfish virtually unchanged, at 59¢; and freshwater drum down 17¢ from a peak of 31¢ in 1931.

The overall effect of the declining demand for freshwater fish and reduced wholesale prices has been a reduction in the number of commercial fishermen as shown in Table 23. The sustained yield of the upper Mississippi River for the past eighty years by a declining number of fishermen is probably the result of increased efficiency of commercial fishing devices (Carlander, 1954: 59-62). Despite the reduction in the numbers of fishermen, the Mississippi River fisheries still play a significant part in the economy of river communities, as noted by Carlander (1954: 70):

Table 77

Calculated Wholesale (Undressed) Prices Paid to Mississippi River Commercial Fishermen Licensed in Illinois for Catches of Carp, Buffalo, Channel Catfish, and Freshwater Drum in [illegible][a]

Year	Carp $/lb.	Carp 1977 $/lb.[b]	Buffalo $/lb.	Buffalo 1977 $/lb.	Channel Catfish $/lb.	Channel Catfish 1977 $/lb.	Freshwater Drum $/lb.	Freshwater Drum 1977 $/lb.
[illegible]	.022	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1922	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.079	[illegible]
1931	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1950	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1955	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.533	[illegible]	[illegible]
1960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1965	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Obtained from Tables 12-20 by dividing the dollar value of the catch by the catch in pounds.

[b] Obtained by using conversion factors in Table 71.

In addition to the . . . fishermen who receive all or much of their income directly from the fisheries, there are /those/ who derive income from the shipping and marketing of the fishery products. The net manufacturers, box makers, boat builders, and manufacturers of outboard motors, boots, slickers, and numerous other objects profit directly from the fishing industry.

Sport Fishery -- Illinois River

The once great sport fishery along the middle reach of the Illinois River has been adequately described elsewhere (Mills et al., 1966). While we did not locate any accounts of fishing in the lower reach of the Illinois River, places such as Meredosia Lake (river mile 72-76) probably offered sport fishing comparable to that in the lakes near Havana (river mile 120). The results of scientific surveys of the fish populations in Meredosia Lake in 1931 and 1934 (Table 28) indicate that black crappie, white crappie, bluegill, and yellow bass were abundant, even though the successive droughts of 1929, 1930, and 1931 had drastically reduced the fish populations in most lakes in Illinois (Department of Registration and Education, 1932: 35). A comparison of the 1942 catch of game fish from Meredosia Bay or Lake with the catch from other locations in the main channel or side channels of the lower Illinois River shows that 60.27 game fish per net-day were taken from the lake, while the next taken elsewhere was 26.87 game fish per net-day at Kampsville (Table 29). Recent surveys by the Illinois Department of Conservation show that the game fish remaining in Meredosia Lake are concentrated in a deep hole where fill was removed for a levee and where some groundwater may enter the lake. Meredosia residents have complained to state legislators and to the Illinois Department of Conservation about the filling of the lake with sediment and the decline in fishing. The Illinois State Water Survey reported that Lake Meredosia has lost 46% of its capacity since 1903 (Lee et al., 1976: 7).

The sediment in Lake Meredosia adversely affects water quality and aquatic life, including fish and the food upon which they feed. On August 8 and 9, 1975, the Illinois State Water Survey found that the dissolved oxygen concentration differed by 1.0 mg/l between the surface and the bottom water. This is surprising considering that the depth of the water is only 3 feet and that the lake was being well mixed by wind and wave action at the time the readings were taken. The oxygen stratification was probably due to lessened photosynthetic activity near the bottom and also to the extremely high oxygen demand exerted by

Table 28

Number of Fish Caught Per Net-Day in Meredosia Lake (River Mile 71) in 1931 and 1976[a]

	1931[b]	1976[c]
Largemouth bass	0.07	0.66
Black crappie	50.07	11.77
White crappie	33.15	47.04
Bluegill	9.77	16.18
Green sunfish	0.04	
Pumpkinseed	d	
Warmouth	0.03	0.30
Rock bass	d	
Yellow bass	0.06	10.30
White bass	0.05	0.05
Yellow perch	d	0.02
Game fish subtotal	103.04	87.30
American eel		0.02
Shortnose gar	3.60	0.30
Longnose gar	0.05	
Bowfin	0.16	0.32
Channel catfish	0.55	0.05
Black bullhead	0.70	0.41
Yellow bullhead	0.16	0.09
Brown bullhead	0.54	0.01
Gizzard shad	1.08	17.22
Freshwater drum	0.19	0.07
Carpsuckers	2.16	0.27
Buffalo	0.29	0.27
Shorthead redhorse	0.14	
Carp	1.10	0.30
Mooneye	0.13	
Other fish subtotal	11.04	20.12
Grand total	114.08	107.42

[a]Data from the files of the Illinois Natural History Survey River Research Laboratory at Havana. The nets were 1-inch mesh hoop nets, probably with wings and leads. Collections were made in the summer.

[b]Total fishing effort, 279.50 net-days.

[c]Total fishing effort, 4.00 net-days.

[d]Less than 0.01 fish per net-day.

Table 29

Number of Fish Caught Per Net-Day in the Lower Illinois River in 1962[a]

	RM 1.0-3.0[b]	RM 23.0[c]	RM 30.5[d]	RM 56.0[e]	RM 69.0[f]	RM 71.0[g]	RM 73.0[h]
Largemouth bass	0.35	0.43					0.80
Black crappie	1.90	1.50	9.56	2.53	0.52	3.09	33.67
White crappie	4.72	8.41	10.19	5.58	2.08	2.48	17.33
Bluegill	2.64	3.02	3.92	0.40		1.49	13.65
Bluegill x green sunfish hybrid			0.16				0.10
Warmouth		0.07		0.04			
Yellow bass	0.04		0.47	0.04			0.20
White bass	1.09	1.51	1.25	0.35	0.52		0.60
Sauger	0.42	0.29	0.31	0.09			
Walleye			0.16				
Game fish subtotal	11.16	15.31	26.02	9.03	3.12	7.06	66.35
American eel	0.04	0.29					
Shortnose gar	1.13	0.14	0.31	0.49	1.04	1.61	4.00
Longnose gar	0.21			0.04	0.52	0.12	
Bowfin		0.72				0.37	0.10
Channel catfish	0.32	2.80	0.16	0.18		0.37	0.20
Flathead catfish	0.33	0.57		0.13		0.37	
Black bullhead	0.04			0.04		0.25	1.29
Brown bullhead							0.20
Gizzard shad	2.33	0.57	1.10		2.08	2.60	8.17
Freshwater drum	0.25	6.11	0.78	0.75	0.52	0.25	1.39
Carpsuckers	0.53	0.57	0.16	0.13	1.04	0.37	0.70
Buffalo	0.11	0.22	0.16		0.52	0.37	0.20
Shorthead redhorse		0.07					
Carp	1.13	1.72	0.47	1.24	1.56	1.61	8.67
Mooneye	0.04			0.04		0.12	
Goldeye	0.21			0.04			0.60
Other fish subtotal	6.87	12.63	3.14	3.48	7.28	6.61	25.4
Grand total	18.03	27.94	29.16	12.51	10.40	13.67	91.75

[a]Data from files of the Illinois Natural History Survey River Research Laboratory at Havana. The nets were 1-inch mesh hoop nets, probably with wings and leads. Collections were made in the summer.

[b]Channel at Grafton. Total fishing effort, 28.38 net-days.

[c]Channel near Hardin. Total fishing effort, 13.92 net-days.

[d]Channel at Kampsville ½ mile above ferry. Total fishing effort, 6.39 net-days.

[e]Channel at Florence ½ mile below bridge. Total fishing effort, 22.57 net-days.

[f]Meredosia Island Slough. Total fishing effort, 1.92 net-days.

[g]Channel at Meredosia. Total fishing effort, 8.08 net-days.

[h]Meredosia Bay (Lake). Total fishing effort, 10.04 net-days.

the bottom sediments (up to 86.08 grams of oxygen/m^2/day, when the sediment was disturbed). Butts (unpublished report, 1975: 8) felt that the sediment oxygen demand was high enough, so that without photosynthetic oxygen production during the warm summer months the dissolved oxygen levels in the lake would be severely depleted. Butts (1975: 4-5) found some organisms living on the bottom: phantom midges (Chaoborus sp.) occurred at densities ranging from 129-344/m^2, and the fingernail clams (Sphaerium striatinum and Sphaerium simile) occurred at densities ranging from 86-172/m^2. For comparison, Table 3 shows that the average number of fingernail clams per square meter in the lower 80 miles of the Illinois River channel ranged from 10 in 1915 to 52 in 1964. Paloumpis and Starrett (1960) reported densities of over 24,000 fingernail clams per square meter in Quiver Lake (mile 123) on the Illinois River in 1952. Gale (1969: v) reported that the average number of the fingernail clam, Musculium transversum, at his sampling stations in Pool 19 was 40,000/m^2 and the maximum number was over 100,000/m^2.

In August, 1974, Sparks (1975: 53) found that dissolved oxygen levels in Meredosia Lake were 3 mg/l, while oxygen levels in the river on the same date were 6 mg/l. The readings were taken in the middle of the afternoon on an overcast day, and waves produced by a strong wind were resuspending bottom sediments in the lake. In the lake, a die-off of gizzard shad was occurring, and almost all the fingernail clams maintained in plastic cages on the bottom of the lake had died since they had last been checked in mid-July. On August 7-8, Butts (unpublished report, 1975: 1) also observed dead fish around the lake. Most of the fish were gizzard shad, but some carp and crappie were seen. No submergent or emergent vascular aquatic vegetation has been evident in the lake in recent years.

Hoopnetting surveys of fish populations in the lower Illinois River show that gamefish declined markedly in the main channel and side channels between 1934 and 1942 (Table 30) and declined further between 1942 and 1967 (Tables 30, 31, and 32). In a side channel at Meredosia Island (river mile 69.0), the number of game fish caught per net-day

Table 30

Number of Fish Caught Per Net-Day in the Lower Illinois River near Meredosia (River Miles 69.0-75.9) in 1934, 1942, and 1967[a]

	1934[b]	1942[c]	1942[d]	1967[e]
Largemouth bass	0.33			
Black crappie	8.67	0.52	3.09	1.38
White crappie	1.17	2.08	2.48	0.38
Bluegill	21.67		1.49	0.13
Green sunfish				0.13
Warmouth	0.50			
Yellow bass	0.17			
White bass		0.52		
Game fish subtotal	32.51	3.12	7.06	2.02
American eel	0.17			
Shortnose gar	3.00	1.04	1.61	0.38
Longnose gar	0.50	0.52	0.12	
Bowfin	0.17		0.37	0.12
Channel catfish	0.33		0.37	
Flathead catfish			0.37	
Golden shiner	0.17			
Gizzard shad	0.50	2.08	2.60	3.12
Freshwater drum		0.52	0.25	0.25
Carpsuckers		1.04	0.37	
Buffalo		0.52	0.37	0.12
Carp		1.56	1.61	1.25
Black bullhead			0.25	1.62
Mooneye			0.12	
Other fish subtotal	4.84	7.28	8.41	6.86
Grand total	37.35	10.40	15.47	8.88

[a] Data from the files of the Illinois Natural History Survey's River Research Laboratory at Havana. The nets were 1-inch mesh hoop nets with wings and leads.

[b] Meredosia Island side channel, mile 69.5. Total fishing effort, 6 net-days.

[c] Meredosia Island side channel, mile 69.0. Total fishing effort, 1.92 net-days.

[d] Main channel border, mile 71.0. Total fishing effort, 8.08 net-days.

[e] Main channel border, miles 75.5-75.9. Total fishing effort, 8 net-days.

Table 31

Number of Fish Caught Per Net-Day in the Lower Illinois River near Hardin (River Miles 23.0-25.5) in 1942, 1964, and 1967[a]

	1942[b]	1964[c]	1967[d]
Largemouth bass	0.43		
Black crappie	1.58	6.10	0.33
White crappie	8.41	1.25	0.67
Bluegill	3.02	0.15	0.17
White bass	1.51	0.05	0.17
Warmouth	0.07		
Sauger	0.29		0.17
Game fish subtotal	15.31	7.55	1.51
American eel	0.29		
Freshwater drum	6.11	0.65	0.33
Channel catfish	2.80		
Flathead catfish	0.57		
Bowfin	0.72		
Shortnose gar	0.14	0.35	0.50
Longnose gar			0.33
Shorthead redhorse	0.07	0.05	
Carpsuckers	0.57	0.55	
Buffalo	0.22		
Carp	1.72	0.40	0.33
Gizzard shad	0.57	0.25	5.17
Black bullhead		0.15	
Other fish subtotal	13.78	2.40	6.66
Grand total	29.09	9.95	8.17

[a]Data from the files of the Illinois Natural History Survey's River Research Laboratory at Havana. The nets were 1-inch mesh hoop nets with wings and leads.

[b]Main channel border, mile 23.0. Total fishing effort, 13.92 net-days.

[c]Diamond Island side channel, miles 24.5-25.5. Total fishing effort, 20 net-days.

[d]Diamond Island side channel, miles 24.5-25.5. Total fishing effort, 6 net-days.

Table 32

Number of Fish Caught Per Net-Day in the Lower Illinois River near the Mouth (River Miles 1.0-23.0) in 1942 and 1967[a]

	1942: Channel at Grafton, RM 1.0-3.0[b]	1942: Channel near Hardin, RM 23.0[c]	1967: 12 Mile Island side channel, RM 13.5-13.9[d]
Largemouth bass	0.35	0.43	0.13
Black crappie	1.90	1.58	1.63
White crappie	4.72	8.41	0.88
Bluegill	2.64	3.02	0.12
Warmouth		0.07	0.12
White bass	1.09	1.51	
Yellow bass	0.04		
Sauger	0.42	0.29	
Yellow perch			0.13
Game fish subtotal	11.16	15.31	3.01
American eel	0.04	0.29	
Bowfin		0.72	0.37
Shortnose gar	1.13	0.14	0.87
Longnose gar	0.21		
Carpsuckers	0.53	0.57	
Buffalo	0.11	0.22	
Channel catfish	0.32	2.80	
Flathead catfish	0.53	0.57	
Black bullhead	0.04		
Freshwater drum	0.25	6.11	0.50
Mooneye	0.04		
Goldeye	0.21		
Shorthead redhorse		0.07	
Carp	1.13	1.72	
Gizzard shad	2.33	0.57	6.13
Other fish subtotal	6.87	13.78	7.87
Grand total	18.03	29.09	10.88

[a]Data from the files of the Illinois Natural History Survey's River Research Laboratory at Havana. The nets were 1-inch mesh hoop nets probably with wings and leads.

[b]Total fishing effort, 28.38 net-days.

[c]Total fishing effort, 13.92 net-days.

[d]Total fishing effort, 8 net-days.

declined from 32.5 in 1934 to 3.12-7.06 in 1942, and to 2.02 in 1967 (Table 30). At Hardin (river miles 23.0-25.5) the catch declined from 15.31 game fish per net-day in 1942 to 7.55 in 1964 and 1.51 in 1967 (Table 31). In the channels and side channels near the mouth, the decline was from 11.16-15.31 in 1942 to 3.01 in 1967 (Table 32).

Sparks (1975) reported the results of an electrofishing survey of the Illinois River, conducted annually from 1959 to 1974. Electrofishing methods had not been developed at the time the navigation dams were being constructed. Hence, there are no pre-impoundment electrofishing data. Hoop-netting and electrofishing differ markedly in their efficiency of capture of different species of fish and in efficiency of capture of different sizes of the same species, so the hoop-netting results should not be compared with the electrofishing results. However, the electrofishing results can be used to assess changes in the gamefish in side channels (no electrofishing was done in lakes) of the lower Illinois River between 1959 and the present.

Sparks (1975: 38) reported that white bass in the Illinois River showed a trend of increasing abundance in the downstream direction, with the largest number occurring in Alton Pool. The largest numbers of other game species, such as bluegill, largemouth bass, white crappie and black crappie, occurred in the upstream pools, La Grange and Peoria, which have the most connecting lake acreage. The catch of game fish increased in 1973 and 1974 when water levels were high (Sparks, 1975: 36-37), but the increases were greatest in the pools upstream from the Alton Pool.

Increased flow of water in the Illinois has several beneficial effects on fishes. Flooded areas often provide good spawning sites, with firm bottoms, whereas the bottom in much of the river and its bottomland lakes is covered with flocculent mud. Several people reported that sunfishes were spawning on flooded gravel roads and areas of firm mud or sand in the spring of 1973. Flooded areas also provide good nursery areas for juvenile fish, provided the water does not retreat too soon. An increased current velocity in the river stimulates spawning migrations of species such as white bass. An increased rate of water flow (discharge)

can dilute oxygen-demanding or toxic wastes. Butts _et al_. (1975) report that increased flows in the upper Illinois River initially result in reduced dissolved oxygen levels because combined storm and sanitary sewers overflow to the river, but that during sustained high flows, the oxygen levels are higher than during sustained low flows.

Figure 7 shows that the catch of largemouth bass, a representative game species, has declined in the Alton Pool since the high water years of 1973-74.

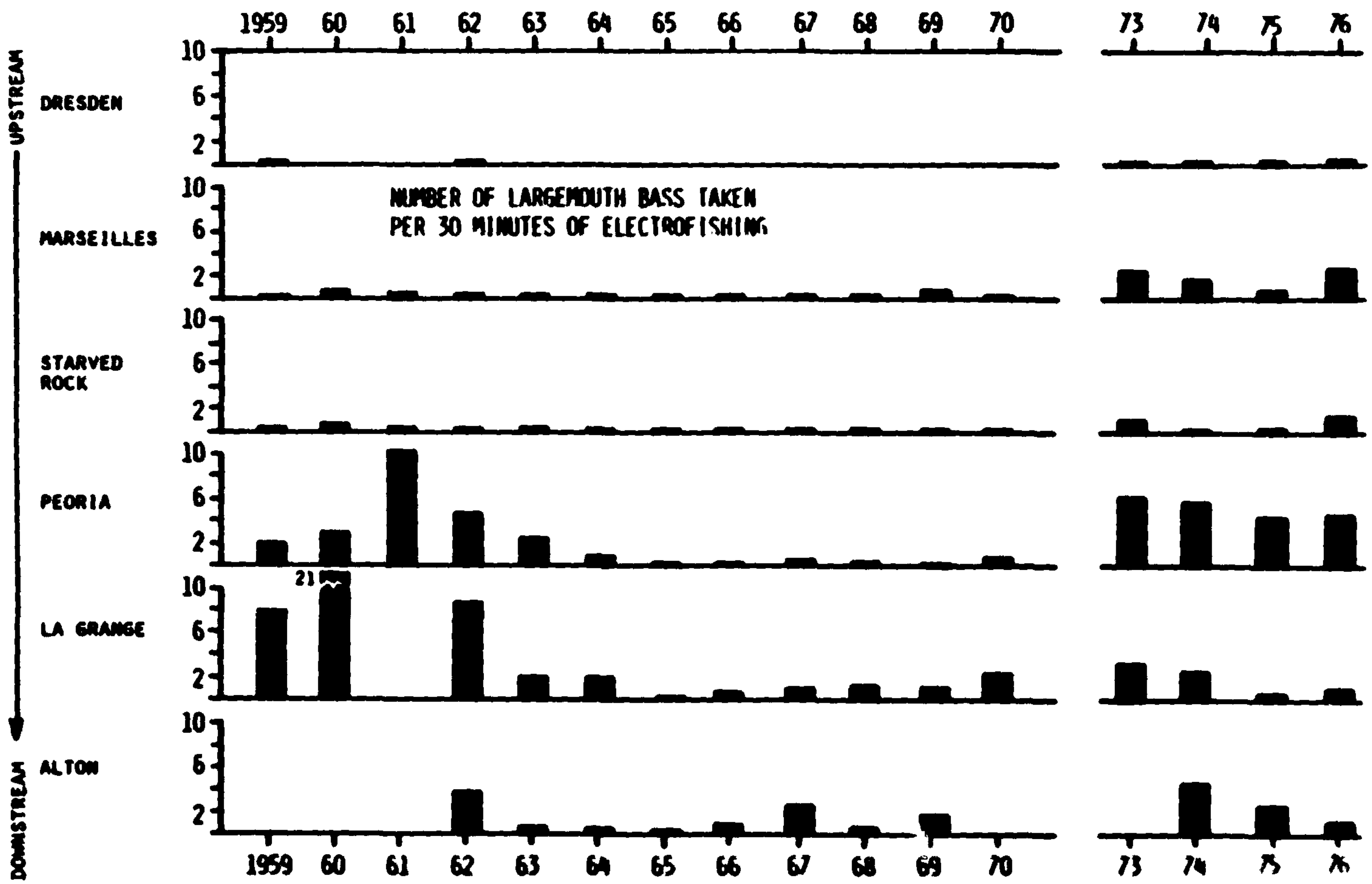


Figure 7. Number of largemouth bass taken per 30 minutes of electrofishing in six pools of the Illinois Waterway from 1959 to 1976. The total number of channel catfish taken at all stations within a pool was divided by the total number of half-hour intervals fished in that pool, to obtain an average catch per unit effort for each pool. The number of electrofishing stations in each pool are: Alton (4 or 5, depending on the year), La Grange Pool (6), Peoria Pool (8), Starved Rock Pool (2), Marseilles Pool (3), and Dresden Pool (1). A small bar (heavy line) indicates that electrofishing was conducted, but few or no fish were taken, while the absence of a bar means no electrofishing was conducted.

Sport Fishery — Mississippi River

An extensive literature search yielded very little quantitative data on the pre-construction sport fishery of the upper Mississippi River. Although several studies provided recent information, it was impossible to perform a quantitative comparison of pre- and post-construction sport fisheries due to the lack of data from the earlier period. An excellent qualitative, historical account of the sport fishery of the upper Mississippi River can be found in Carlander (1954: 71-81).

Green (1960: 6) reported that impoundment of the Mississippi River created 3 distinct habitat zones: (1) an upper pool, exhibiting essentially normal river conditions with deep sloughs and wooded islands, (2) a middle pool, with large areas of comparatively shallow water and adjacent marshes, and (3) a lower pool, with deep, open water and no marsh. Barnickol and Starrett (1951: 313) found that the upper reaches of the navigation pools provided a more favorable habitat for sport fishes than the middle and lower sections and that sport fishing was conducted primarily in the pools below the dams. They attributed the concentration of sport fishes in the upper reaches of each pool to the availability of preferred food items, such as aquatic insects and minnows, and to the occurrence of deep holes and shallow sand bars. Cleary (1961: 143) and Helms (1969: 33) also found that tailwater areas immediately below each dam attracted the most sport fishing pressure. In addition, fish which move upstream at certain times of year, such as white bass, will aggregate below the dams. Sport fishermen are well aware of this concentrating effect of the dams.

Since 1946, a regular count of both boat and shore fishermen using the dams has been made by lockmasters at each lock and dam (Carlander, 1954: 80). Nord (1967: 108-109) presented these counts for 1959-1963. His tabulations revealed that Lock and Dam 26 ranked first among all 26 impoundments in the shore count, with an average annual use by 13,500 fishermen. However, this site ranked 23rd in the boat count, with only 380 boat fishermen per year recorded. The shore fishermen are probably people from the neighboring St. Louis area with relatively

low incomes, who cannot afford boats or lengthy trips. Fishermen who can afford boats evidently choose to go upstream of Lock and Dam 26. Lock and Dam 25 ranked 3rd and 4th in shore and boat counts, respectively. Lock and Dam 24 had respective shore and boat counts which ranked 17th and 11th during the 1950-1963 period.

Several Mississippi River sport fishery surveys have been conducted under the auspices of the Upper Mississippi River Conservation Committee (UMRCC). The years of these surveys were: 1956-1957 (Klaas and Vidal, 1958), 1962-1963 (Nord, 1964), 1967-1968 (Wright, 1970), and 1972-1973 (Fleener, 1975). All navigation pools were censused in the 1956-1957 period. Only Pools 4, 5, 7, 11, 13, 18, and 26 were surveyed in the three latter periods.

Table 33 shows comparative summaries of creel data from the four UMRCC sport fishery surveys for Pool 26. The values indicate that the greatest catch rate (0.625 fish per man-hour) for this pool occurred in the 1956-1957 period. The lowest rate (0.374 fish per man-hour) was recorded in 1962-1963. Pool 26 ranked 7th among the 26 upper Mississippi River pools censused in 1956-1957 and ranked last among seven pools in the three later surveys.

The species composition of the sport catch in Pool 26 in 1962-1963, 1967-1968, and 1972-1973 is shown in Table 34. Freshwater drum ranked first in the catch by sport fishermen, averaging 27 percent of the total harvest for the three census periods. The top five species in order of abundance in the sport catch were: 1962-1963, freshwater drum, channel catfish, crappie, bluegill, and carp; 1967-1968, freshwater drum, white bass, bluegill, green sunfish, and channel catfish; and 1972-1973, freshwater drum, channel catfish, carp, crappie, and green sunfish.

All four UMRCC sport fishery surveys indicated that the preponderance of anglers fishing Pool 26 were from Missouri, primarily the St. Louis area. The remainder were from border counties in Illinois.

During 1970, the Illinois Department of Conservation made an aerial recreation survey of Mississippi River Pools 12-26 (Dunham, 1970a). Aerial counts of fishing boats, boat fishermen, bank fishermen, and pleasure craft were made on a weekday, a weekend day, and a holiday (July 4).

Table 33

<u>Summary of Creel Data for Pool 26 of the Upper Mississippi River for 1956-1957, 1962-1963, 1967-1968, and 1972-1973</u>

Date	Number of Anglers Contacted	Number of Fish Creeled	Total Hours Fished	Fish per Man-Hour
1956-1957[a]	[illegible]	[illegible]	2,170	0.62[illegible]
1962-1963[b]	2,427	2,710	7,271	0.374
1967-1968[c]	1,914	2,006	6,939	0.300
1972-1973[d]	1,465	1,500	3,[illegible]	0.400

[a]Klaus and Vidal, 1958: 207.

[b]Nord, 1964: 195.

[c]Wright, 1970: 116.

[d]Fleener, 1975: [illegible].

Table 3x

Species Composition of Sport Catch and Ranking by Numbers Caught During Creel Census Periods in Pool 26 of the Mississippi River in 1962-1963, 1967-1968, and 1972-1973

Species	1962 - 1963[a] No.	%	Rank	1967 - 1968[b] No.	%	Rank	1972 - 1973[c] No.	%	Rank
Paddlefish							2	0.1	18
Lake sturgeon									
Shovelnose sturgeon	1	tr.	13				2	0.1	18
Gar spp.	1	tr.	13	2	0.07	18	13	0.9	11
Bowfin	1	tr.	13	2	0.07	18	3	0.2	17
Gizzard shad	2	tr.	12				64	2.9	9
Mooneye				1	0.03	19			
Northern pike									
Carp	597	7.0	7	186	6.50	7	408	18.4	[illegible]
Sucker spp.	2	tr.	12	7	0.24	14	6	0.3	16
Blue catfish	38	1.4	8	43	1.50	8	20	1.0	11
Channel catfish	687	25.0	2	676	23.60	2	424	19.1	[illegible]
Flathead catfish	50	1.8	[illegible]	26	0.90	12	84	4.2	8
Bullhead spp.	11	tr.	10	12	0.41	10	6	0.3	16
American eel	4	tr.	11	3	0.10	17	6	0.2	16
White bass	62	2.0	6	554	19.00	2	80	3.2	6
Yellow bass	1	tr.	13				2	0.1	18
Rock bass									
Warmouth				44	1.50	9	3	0.1	17
Green sunfish	1	tr.	13	473	16.37	4	363	0.1	[illegible]
Orangespotted sunfish									
Bluegill	376	14.0	4	443	15.20	3	71	4.7	7
Other sunfishes				33	1.14	11			
Smallmouth bass				1	0.03	19	2	0.1	18
Largemouth bass	26	1.0	9	30	1.10	12	15	0.7	12
Crappie spp.	477	18.0	3	209	7.20	6	190	10.5	4
Yellow perch									
Sauger	27	tr.	9	4	0.14	16			
Walleye	1	tr.	13	12	0.41	14	3	0.3	12
Freshwater drum	898	33.0	1	565	19.43	1	651	29.9	1
Total	2,718			2,904			1,980		

[a] Ford, 1964: 102.

[b] Wright, 1970: 102.

[c] Fleener, 1975: 270.

In order of importance, the [illegible] showed the greatest usage by fishermen, boaters, and campers [illegible] in Pools 24, 25, 26, 28, 27, and [illegible] ([illegible], 1978a, b). Pool [illegible] received the greatest use of all the pools by pleasure craft, water skiers, swimmers, and commercial barge traffic.

Between 1970–1974, the Illinois Department of Conservation conducted electrofishing surveys in the tailwater habitats below navigation dams [illegible] on the Mississippi River. The results of these surveys were reported by [illegible] (1970b), [illegible] (1971), [illegible] and [illegible] (1972), [illegible] and [illegible] (1973), and [illegible] and [illegible] (1974). Results of the 1974 survey for Pools 24, 25, and 26 are shown in Table 37 and a summary of the catch of game, commercial, and forage fish in these pools is given in Table 38. The data show that game fish species comprised a small percentage (range [illegible] percent) of the total catch in all 3 pools. Commercial species constituted the largest percentage (71 percent) of the catch in Pools 24 and 26. Forage species, primarily gizzard shad, were most abundant in Pool 25, where they comprised 63 percent of the total collection.

Questionnaire results of fishermen, creel censuses, and aerial recreation surveys all indicate that the upper Mississippi River navigation pools receive a great amount of sport fishing pressure. Backwater areas, bottomland lakes, and tailwater habitats below dam structures are all actively used for sport fishing. Impoundment of the upper Mississippi River tended to concentrate sport fishing activities in the upper reaches of each pool. The upper pool areas have been least affected by impoundment in that they exhibit essentially normal river conditions with aquatic habitat types conducive to the production of sport fish species.

Table 25

Numbers (Per Hour by Electrofishing) and Percent Composition of Fish Collected in the Tailwaters of Locks and Dams 24, 25, and 26, Mississippi River in 1971

Species	Pool 24 No.	Pool 24 %	Pool 25 No.	Pool 25 %	Pool 26 No.	Pool 26 %
Paddlefish						
Longnose gar						
Shortnose gar			5	2.1	1	0.7
Bowfin						
American eel	3	2.7			1	0.7
Skipjack herring					1	0.7
Gizzard shad	44	40.0	147	62.3	53	35.8
Goldeye	1	0.9				
Mooneye	3	2.7	1	0.4		
Northern pike						
Carp	29	26.4	27	11.4	30	20.3
River carpsucker	5	4.5			1	0.7
Quillback carpsucker						
Highfin carpsucker						
Blue sucker						
Smallmouth buffalo	3	2.7	1	0.4		
Bigmouth buffalo			4	1.7	1	0.7
Goldfish					2	1.4
Spotted sucker						
Golden redhorse	1	0.9				
Northern redhorse					4	2.7
Stonecat						
Channel catfish	1	0.9	1	0.4	3	2.0
Flathead catfish	1	0.9			3	2.0
White bass	3	2.7	8	3.4	4	2.7
Yellow bass						
Rock bass						
Warmouth						
Green sunfish						
Pumpkinseed						
Orangespotted sunfish						
Bluegill	1	0.9				
Smallmouth bass						
Largemouth bass	1	0.9	4	1.7	1	0.7
White crappie			4	1.7		
Black crappie	1	0.9	3	1.3	5	3.4
Yellow perch						
Sauger						
Walleye						
Freshwater drum	9	8.2	31	13.1	9	6.1
Total	110		236		148	

Source: Dunham, 1971.

Table [illegible]

Number and Percent Composition of Game, Forage, and Commercial Fish Collected per Hour of Electrofishing in the Tailwaters of Locks and Dams [illegible], Mississippi River During [illegible]

Lock and Dam Number	Game Fish No.	Game Fish %	Commercial Fish No.	Commercial Fish %	Forage Fish No.	Forage Fish %	Total No.	Total %
26	8	[illegible]	30	[illegible]	66	[illegible]	110	100
27	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100
28	14	[illegible]	[illegible]	[illegible]	32	[illegible]	148	100

Source: [illegible]

Scientific Surveys of Fish Species Present in 1876-1903 and 1944-1971 in the Upper Mississippi River

Table 37 compares fish species taken from the upper Mississippi River in a pre-construction scientific survey between 1876 and 1903 (Forbes and Richardson, 1920) and a post-construction scientific survey between 1944 and 1972 (Smith et al., 1971). Specimens for most records were identified by Illinois Natural History Survey taxonomists and deposited in the fish collection of that agency.

In the 1876-1903 survey, 90 individual species were collected as compared to 84 species in the 1944-1971 period. Fourteen species which were present in the early period were not present in the recent period. These included 3 commercial species (pallid sturgeon, river redhorse, and brown bullhead), 1 predatory species (alligator gar), and 10 forage species (mud minnow, Ozark minnow, blackchin shiner, blacknose shiner, redfin shiner, steelcolor shiner, Southern redbelly dace, lake chubsucker, freckled madtom, and crystal darter).

Thirteen species were collected between 1944-1971 which were not present in the 1876-1903 period. These species were: 2 commercial species (spotted sucker and yellow bullhead), 10 forage species (speckled chub, pallid shiner, ghost shiner, spotfin shiner, sand shiner, weed shiner, mimic shiner, trout perch, mud darter, and river darter), and the chestnut lamprey.

In addition, 8 species were collected between 1944 and 1972 which were classified as accidental stragglers from tributary streams. These included: rainbow trout, creek chub, burbot, redear sunfish, rainbow darter, fantail darter, banded darter, and blackside darter.

Table 37

A Comparison of Fish Species Present in the Illinois River and Upper Mississippi River (Pools 14-26) for Periods Before and After Construction of the Nine-Foot Channel Navigation System

Species	Illinois River 1876-1903[a]	Illinois River 1950-1977[b]	Upper Mississippi River 1876-1903[a]	Upper Mississippi River 1944-1971[c]
Chestnut lamprey, *Ichthyomyzon castaneus*		x		x
Silver lamprey, *Ichthyomyzon unicuspis*	x	x	x	x
Lake sturgeon, *Acipenser fulvescens*, C	x	x	x	x
Pallid sturgeon, *Scaphirhynchus albus*, C			x	
Shovelnose sturgeon, *Scaphirhynchus platorynchus*, C	x	x	x	x
Paddlefish, *Polyodon spathula*, C	x	x	x	x
Longnose gar, *Lepisosteus osseus*, P	x	x	x	x
Shortnose gar, *Lepisosteus platostomus*, P	x	x	x	x
Alligator gar, *Lepisosteus spatula*, P	x		x	
Bowfin, *Amia calva*, P	x	x	x	x
American eel, *Anguilla rostrata*, C	x	x	x	x
Skipjack herring, *Alosa chrysochloris*, F	x	x	x	x
Gizzard shad, *Dorosoma cepedianum*, F	x	x	x	x
Goldeye, *Hiodon alosoides*, F	x	x	x	x
Mooneye, *Hiodon tergisus*, F	x	x	x	x
Rainbow trout, *Salmo gairdneri*, S		x*		x*
Mudminnow, *Umbra limi*, F	x	x	x	
Grass pickerel, *Esox americanus*, S	x	x	x	x
Northern pike, *Esox lucius*, S	x	x	x	x
Muskellunge, *Esox masquinongy*, S	x			
Stoneroller, *Campostoma anomalum*, F	x	x	x	x
Ozark minnow, *Dionda nubila*, F			x	
Carp, *Cyprinus carpio*, C	x	x	x	x
Silverjaw minnow, *Ericymba buccata*, F	x	x		
Silvery minnow, *Hybognathus nuchalis*, F	x	x	x	x
Speckled chub, *Hybopsis aestivalis*, F		x		x
Silver chub, *Hybopsis storeriana*, F	x	x	x	x
Hornyhead chub, *Nocomis biguttatus*, F		x		

Key: x=present, x*=presence is accidental, C=commercial fish, S=sport fish, P=predatory fish, F=forage fish. Classifications of fish are those used by Bernickel and Starrett (1951) or designated by authors.

[a] Forbes, 1920.

[b] Unpublished data from files of the late Dr. W.C. Starrett, 1950-1972 and Dr. R.E. Sparks, 1972-present, Illinois Natural History Survey.

[c] Smith et al., 1971.

Sheet 1 of 4

Table 37 (continued)

Species	Illinois River 1876-1903	Illinois River 1950-1977	Upper Mississippi River 1876-1903	Upper Mississippi River 1944-1971
Golden shiner, Notemigonus chysoleucas, F	x	x	x	x
Pallid shiner, Notropis amnis, F				x
Pugnose shiner, Notropis anogenus, F	x			
Emerald shiner, Notropis atherinoides, F	x	x	x	x
River shiner, Notropis blennius, F	x	x	x	x
Ghost shiner, Notropis buchanani, F		x		x
Striped shiner, Notropis chrysocephalus, F		x		
Common shiner, Notropis cornutus, F	x		x	x
Bigmouth shiner, Notropis dorsalis, F	x	x	x	x
Pugnose minnow, Notropis emiliae, F	x	x	x	x
Blackchin shiner, Notropis heterodon, F	x		x	
Spottail shiner, Notropis hudsonius, F	x	x	x	x
Blacknose shiner, Notropis heterolepis, F	x		x	
Red shiner, Notropis lutrensis, F	x	x	x	x
Duskystripe shiner, Notropis pilsbryi, F	x			
Rosyface shiner, Notropis rubellus, F	x			
Silverband shiner, Notropis shumardi, F	x	x	x	x
Spotfin shiner, Notropis spilopterus, F		x		x
Sand shiner, Notropis stramineus, F		x		x
Weed shiner, Notropis texanus, F				x
Redfin shiner, Notropis umbratilis, F	x	x	x	
Mimic shiner, Notropis volucellus, F				x
Steelcolor shiner, Notropis whipplei, F	x		x	
Suckermouth minnow, Phenacobius mirabilis, F	x	x	x	x
Southern redbelly dace, Phoxinus erythrogaster, F	x		x	
Bluntnose minnow, Pimephales notatus, F	x	x	x	x
Fathead minnow, Pimephales promelas, F	x	x	x	x
Bullhead minnow, Pimephales vigilax, F	x	x	x	x
Blacknose dace, Rhinichthys atratulus, F	x			
Creek chub, Semotilus altromaculatus, F	x	x	x	x*
River carpsucker, Carpiodes carpio, C	x	x	x	x
Quillback carpsucker, Carpiodes cyprinus, C	x	x	x	x
Highfin carpsucker, Carpiodes velifer, C	x	x	x	x
White sucker, Catastomus commersoni, C	x	x	x	x
Blue sucker, Cycleptus elongatus, C	x	x	x	x
Northern hog sucker, Hypentelium nigricans, C	x	x	x	x
Lake chubsucker, Erimyzon sucetta, F	x		x	

Sheet 2 of 4

Table 37 (continued)

Species	Illinois River 1876-1903	Illinois River 1950-1977	Upper Mississippi River 1876-1903	Upper Mississippi River 1944-1971
Smallmouth buffalo, Ictiobus bubalus, C	x	x	x	x
Bigmouth buffalo, Ictiobus cyprinellus, C	x	x	x	x
Black buffalo, Ictiobus niger, C	x	x	x	x
Spotted sucker, Minytrema melanops, C	x			x
Silver redhorse, Moxostoma anisurum, C	x	x	x	x
Golden redhorse, Moxostoma erythrurum, C	x	x	x	x
Shorthead redhorsee, Moxostoma macrolepidotum, C	x	x	x	x
River redhorse, Moxostoma carinatum, C	x		x	
White catfish, Ictalurus catus, C		x		
Blue catfish, Ictalurus furcatus, C	x	x	x	x
Black bullhead, Ictalurus melas, C	x	x	x	x
Yellow bullhead, Ictalurus natalis, C	x	x		x
Brown bullhead, Ictalurus nebulosus, C	x	x	x	
Channel catfish, Ictalurus punctatus, C	x	x	x	x
Stonecat, Noturus flavus, F	x	x	x	x
Tadpole madtom, Noturus gyrinus, F	x	x	x	x
Freckled madtom, Noturus nocturnus, F	x		x	
Flathead catfish, Pylodictis olivaris, C	x	x	x	x
Pirate perch, Aphredoderus sayanus, F	x			
Trout perch, Percopsis omiscomaycus, F	x	x		x
Burbot, Lota lota, C	x*	x*		x*
Banded killifish, Fundulus diaphanus menona, F	x			
Starhead topminnow, Fundulus notti, F	x	x		
Blackstripe topminnow, Fundulus rotatus, F	x	x	x	x
Mosquitofish, Gambusia affinis, F	x	x	x	x
Brook silverside, Labidesthes sicculus, F	x	x	x	x
Brook stickleback, Culaea inconstans, F	x			
White bass, Morone chrysops, S	x	x	x	x
Yellow bass, Morone mississippiensis, S	x	x	x	x
Rock bass, Ambloplites rupestris, S	x	x	x	x
Flier, Centrarchus macropterus, S	x			
Green sunfish, Lepomis cyanellus, S	x	x	x	x
Pumpkinseed, Lepomis gibbosus, S	x	x	x	x
Warmouth, Lepomis gulosus, S	x	x	x	x
Orangespotted sunfish, Lepomis humilis, S	x	x	x	x
Bluegill, Lepomis macrochirus, S	x	x	x	x
Longear sunfish, Lepomis megalotis, S	x			
Redear sunfish, Lepomis microlophus, S		x		x*
Bantam sunfish, Lepomis symmetricus, S	x			
Smallmouth bass, Micropterus dolomieui, S	x	x	x	x
Largemouth bass, Micropterus salmoides, S	x	x	x	x

Sheet 3 of 4

Table 37 (concluded)

Species	Illinois River 1876-1903	Illinois River 1950-1977	Upper Mississippi River 1876-1903	Upper Mississippi River 1944-1971
White crappie, *Pomoxis annularis*, S	x	x	x	x
Black crappie, *Pomoxis nigromaculatus*, S	x	x	x	x
Crystal darter, *Ammocrypta asprella*, F			x	
Western sand darter, *Ammocrypta clara*, F	x		x	x
Mud darter, *Etheostoma asprigene*, F		x		x
Rainbow darter, *Etheostoma caeruleum*, F	x		x	x*
Bluebreast darter, *Etheostoma camurum*, F	x			
Bluntnose darter, *Etheostoma chlorosomum*, F		x		
Iowa darter, *Etheostoma exile*, F	x			
Fantail darter, *Etheostoma flabellare*, F	x		x	x*
Least darter, *Etheostoma microperca*, F.	x			
Johnny darter, *Etheostoma nigrum*, F	x	x	x	x
Orangethroat darter, *Etheostoma spectabile*, F		x		
Banded darter, *Etheostoma zonale*, F	x			x*
Yellow perch, *Perca flavescens*, S	x	x	x	x
Logperch, *Percina caprodes*, F	x	x	x	x
Blackside darter, *Percina maculata*, F	x	x	x	x*
Slenderhead darter, *Percina phoxocephala*, F	x	x	x	x
River darter, *Percina shumardi*, F	x	x		x
Sauger, *Stizostedion canadense*, S	x	x	x	x
Walleye, *Stizostedion vitreum*, S	x	x	x	x
Freshwater drum, *Aplodinotus grunniens*, C	x	x	x	x
Banded sculpin, *Cottus carolinae*, F	x			
Total number of species present (excluding x*)	109	92	90	85
Number of species present in early period, not present in recent period (excluding x*)		-28		-18
Number of species present in recent period, not present in early period (excluding x*)		+11		+13

Sheet 4 of 4

Summary of Effects of the Nine-Foot Navigation System on Fish in the Upper Mississippi River

The dams constructed in the 1930's as part of the nine-foot navigation system impound water during low river stages to provide a depth of at least nine feet in the channel. The dams initially increased the amount of slack-water habitat available during the normal low-flow periods, with the greatest increases occurring in the reaches closest to the dams. During high river stages, the gates in the navigation dams are opened, and water levels are free to fluctuate as they did in pre-construction times.

The environmental impacts resulting from the operation and maintenance of this navigation system have concerned biologists since its inception. Methods of operation and maintenance with potential impacts on the river biota include pool regulation, maintenance dredging of the channel, disposal of dredged material, the construction and maintenance of regulatory works such as dikes and bank revetments, and the maintenance of locks and dam structures (Colbert et al., 1975: 17).

The difficulty encountered in determining the specific effects various alterations have had on the fish and wildlife of the upper Mississippi River can be attributed to the paucity of pre-construction data mentioned elsewhere in this report. Gunter (1957: 13) in addressing this problem at the 22nd North American Wildlife Conference stated:

> It has been suggested to me that some statement about the amount of the wildlife and aquatic life decrease along the river should be made. It would be a matter of comparing what the valley was in its pristine glory as a wildlife habitat and what it is today. But this is impossible. Wildlife biologists did not exist in the days when the life along the river began to decline. All we can say today is that wildlife and aquatic life has declined because its habitat has largely been destroyed. Great changes have taken place and their general outlines are obvious. The specific and exact changes are unknown.

Other changes were taking place in the Mississippi River valley during this period that compounded the problem of identifying particular

cause-and-effect relationships. Man's activities in the river basin resulted in increased industrial, municipal, and agricultural pollution. The construction of levee districts and drainage of bottomlands for agricultural purposes removed fish spawning and feeding areas. Carlander (1954: 25) described this complexity:

> Man has changed the Upper Mississippi River both deliberately and indirectly. These changes have had their effect both on fish and on fishing methods. It is almost impossible to separate the effects of the various changes, or even to say whether the individual changes were favorable or unfavorable to the fishery resources of the river.

Effects of Increased Water Area and Reduced Discharge. Two initial effects of impoundment were an increase in the permanent water area and a decrease in river discharge. New aquatic habitat was created by inundation of terrestrial areas. Within the study area of Pools 24, 25, and 26, there are approximately 73 square miles of aquatic habitat at normal pool elevations (Colbert et al., 1975: 32). Although this certainly represents a gain in aquatic habitat due to impoundment, comparable pre-construction acreage was unavailable at this writing.

Carlander (1954: 21) felt that the decrease in river current affected the fish and fishing more than the increased and stabilization of the water area. Although fish spawning and feeding areas were increased following impoundment, Carlander (1954: 21) noted that as the current slowed, silt settled out and covered these important areas. Bellrose et al. (1977: C-112) found that this also occurred in the Illinois River valley following impoundment.

As specific riverine habitats were reduced following impoundment, one would expect changes in the fish species composition. In a previous section, we noted that the species composition in the upper Mississippi River has remained almost the same for the

past 100 years. However, 10 forage species were lost in the period 1903-1944 based on a comparison of pre- and post-construction scientific surveys. These included the mudminnow, Ozark minnow, blackchin shiner, blacknose shiner, redfin shiner, steelcolor shiner, Southern redbelly dace, lake chubsucker, freckled madtom, and crystal darter. An examination of fish habitat requirements (Trautman, 1957) revealed that most of these species preferred a clear-water environment with sand or gravel bottoms and appreciable current. The mudminnow was found to require a soft bottom, but undisturbed clear water (Trautman, 1957: 205). Smith (1971: 9) stated that the mudminnow, lake chubsucker, and blackchin shiner ranges in Illinois shrunk most likely as a result of floodplain drainage of lakes and sloughs marginal to large rivers.

In addition to the loss of certain forage species, 3 commercial species (pallid sturgeon, river redhorse, and brown bullhead) and a predatory species (alligator gar) virtually disappeared from the upper Mississippi River between 1903 and 1944. The pallid sturgeon was considered rare in the upper Mississippi River in the period 1876-1903 and was thought to prefer a swift-water habitat (Forbes, 1920: 29). In a 1944-1946 survey, Barnickol and Starrett (1951: 290) found that this species only occurred in the Mississippi near its confluence with the Missouri. The river redhorse was described as intolerant of turbidity and siltation (Trautman, 1957: 262). The brown bullhead was also considered sensitive to turbid waters (Trautman, 1957: 426). In 1944-1946 collections, the alligator gar was found predominantly in the unpooled section of the Mississippi River between Alton, Illinois and Caruthersville, Missouri (Barnickol and Starrett, 1951: 320).

As described above, most of the fish species which disappeared from the upper Mississippi River required clear, fast-flowing water environments with sand or gravel bottoms and were intolerant of siltation and

turbidity. Impoundment of the upper Mississippi River as part of the nine-foot navigation system probably reduced current velocities and increased siltation rates. The combined effects of turbidity and siltation altered specific riverine habitats and probably contributed to the decline of these species. Dams and impoundments ranked sixth in a list of factors responsible for the decimation of certain native Illinois fish (Smith, 1971: 14). Excessive siltation ranked first (Smith, 1971: 8).

Effect of Dams on Fish Migration. Dams can block the natural migration and dispersal of fish (Smith, 1971: 13). Hubley (1961: 8) reported that the locks and dams were not barriers to channel catfish movements in the upper Mississippi River from Bay City, Wisconsin to Lansing, Iowa based on recovery of tagged fish.

No specific information was available on the effects of locks and dams 24, 25, and 26 on fish migration.

Effects of Winter Drawdowns. An early operational procedure of the nine-foot navigation system that had a measurable effect on fish was winter drawdown. To provide adequate depths of water for winter navigation in the lower Mississippi River, it was sometimes necessary to release water from the upper navigation pools. Carlander (1954: 23) stated that these sudden and drastic lowerings of water in the upper pools often left thousands of fish stranded in pools isolated from the main channel. On many occasions, thousands of fish were killed. Greenbank (1946, in Keenlyne, 1974: 24) found that winter drawdowns led to oxygen depletion and fish destruction and that they seemed to have had a greater deleterious effect on game fishes such as bass, bluegill, and crappie than on yellow perch, pike perch, catfish, and the rough or commercial fishes.

Winter drawdowns also prompted fish movements from the backwater areas. Christenson and Smith (1965: 46) reported that falling water levels during the winter were accompanied by a definite movement out of backwater areas in Pools 8 and 9 by carp, Northern pike, crappies, spotted sucker, and bowfin. They also found that movement of these fish was intensified by a sharp drop in the water stage.

In interviews with commercial fishermen, Smith (1946: 6) reported

that 96 out of 101 fishermen stressed the necessity of maintenance of uniform pool levels as far as possible. They thought that winter fluctuations resulted in a decrease in fish populations and condition.

Regarding the effects of winter drawdowns on fish in Pools 24, 25, and 26, the Fisheries Technical Section of the Upper Mississippi River Conservation Committee (UMRCC, 1951: 25) reported that:

> in 1945-1946 . . . an estimated 15,811 pounds of dead fish were observed in Pool 25 (Lincoln Co., Mo.) . . . rescue crews obtained approximately 4,000 pounds of fish (from Pool 25) . . . observers estimated 19¾ tons of fish were removed by the public from sites in the area and about 11 tons were harvested commercially near Ellsberry, Mo. During the 1949-50 non-navigation season, neither Pool 24 nor 26 were included in the intensive drawdown. The fluctuation of the water level in these 2 pools was relatively slight and no fish mortality was reported in either pool . . . during the same period, fish kills were noted in other pools which were drawn down.

Winter drawdown has not been practiced by the St. Louis District since 1970. Natural fluctuations in water levels stranded fish in backwaters in pre-construction as well as post-construction times.

Fish rescue operations were relatively expensive, and there was never any sound evidence that they had a beneficial effect on fish populations in the river.

Fall and winter drawdowns are sometimes used as a fish management tool in relatively deep reservoirs, as a result of favorable results obtained in places like the Tennessee Valley. One purpose of reservoir drawdown is to force young fish out of protected shallows into deeper water, where they can be preyed upon by larger fish, thus preventing an overpopulation of stunted fish which are undesirable for a sport fishery. Overpopulation and stunting can occur in reservoirs, which are semi-closed systems. Stunting and overpopulation were never problems in large open systems like the Illinois and Mississippi Rivers, where exchanges of fish between backwaters and the rivers could occur during times of high water. The very shallow lakes and backwaters along the Mississippi

are subject to drying out during the summer, and to winterkill when there is ice and snow cover coupled with an oxygen demand exerted by sediment. These areas would have no fish until they were reflooded by rising water levels and fish were recruited from the river.

While the effect of summerkill or winterkill on fish populations in the total river system is probably not detectable, the local effect on a favorite fishing area can be disastrous, though temporary. Management of water levels in the pools, or construction of low levees to retain water in fishing areas during low-flow periods might alleviate the problem temporarily, although sedimentation continues to make the lakes and backwaters shallower and more subject to summerkill and winterkill.

Effects of Other Operation and Maintenance Activities. In addition to pool regulation, other methods of operation and maintenance of the nine-foot navigation system include: maintenance dredging of the channel, disposal of dredged material, the construction and maintenance of regulatory works such as dikes and bank revetments, and the maintenance of the lock and dam structures (Colbert et al., 1975: 117). The potential environmental impacts of these practices were described by Colbert et al. (1975: 120-127). However, an extensive literature search yielded very little information on actual impacts that have occurred within Pools 24, 25, and 26 as a result of these procedures.

Kelley (1949, in Koenlyne, 1974: 145) reported that occasional complaints were received by him from people living along the river regarding the disposal of dredge spoil. He stated that the greatest concern was the placement of spoil on fish spawning beds in slough mouths. Reportedly, this material washed back into the river and disturbed either fish or fishing.

In 1969, a dredge spoil survey was conducted by several state conservation agencies, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers (Robinson, 1970). The study recommended spoil and no-spoil areas for dredge disposal from Hastings, Minnesota to Cairo, Illinois to prevent further destruction of aquatic habitat. The Corps of Engineers now coordinates annually with the U.S. Fish and Wildlife Service and the state conservation agencies regarding dredge spoil disposal.

Wetland Vegetation

Wetland vegetation provides important food resources and habitat for both fish and wildlife. Therefore any change in the wetland vegetation will profoundly affect the entire riverine ecosystem. Aquatic, marsh, and moist soil vegetation in the Mississippi and Illinois River valleys has been affected by (1) fluctuating water levels and (2) sedimentation and turbidity. Although most of our quantitative data are from the Mark Twain National Wildlife Refuge at Calhoun and Batchtown, it is felt that these areas are indicative of the changes that occurred throughout Pools 24, 25, and 26.

The implementation of the nine-foot channel increased low water levels upstream from the dams. Low water levels have generally been stabilized. However, fall drawdowns, a result of pool operations, adversely affected wetland vegetation during the 1950's and 1960's. These drawdowns have been curtailed since 1970.

Effects of Fluctuating Water Levels. Most aquatic plant communities are adapted to specific parameters of moisture and water levels. Fluctuating water levels affect aquatic plant communities on a short-term basis. The fluctuation of water levels determines, to an extent, which plant communities will become dominant for a given year. However, when water levels are permanently raised, such as by the nine-foot channel project, a transition takes place replacing former dominant plant communities with new ones. Such a situation was documented at Calhoun Point by Yeager (1949: 56-57). He reported that former bottomland timber areas were converted to marsh, and extensive growths of submerged aquatics grew in the expanded backwater areas.

Maximum production of submerged aquatic plants depends upon stable water levels (Bellrose et al., 1977: C-36). Gauge readings at Grafton, Illinois for 1943 indicate a substantial June flood. Extreme flood conditions severely decreased submerged aquatic production in 1943, 1944, and 1945 (Yeager, 1949: 55). These major water level fluctuations adversely affected submerged plant production at Flat and Gilbert Lakes in Pool 26, Illinois River (Tables 38 and 39). Refuge narrative reports for the Batchtown and Calhoun units indicated that during the years when stable water levels occurred, submerged aquatic plants flourished. Water levels on Pool 26 were relatively stable during the growing season for most of the years between 1948 and 1968, except for 1951, 1960, and 1967 when water levels fluctuated during the

Table 30

[illegible]

Species	1961	1962	1963	1964
Cattail		35.3		
Longleaf pondweed	24.0			
Leafy pondweed	1.6			
Sago pondweed	1.6			
Bushy pondweed	65.6			
Lophotocarpus	59.[illegible]	2.2		
Rice cutgrass	29.8	9.[illegible]		
Wild millet				6.0
Cyperus	98.1			22.7
Softstem bulrush	1.0			
Spike rush	6.0			
Marsh smartweed		47.9	31.7	22.0
Coontail	49.1			
American lotus	83.3		6.7	27.3

Table [illegible]

[illegible]

Species	1961	1962	1963	1964
Cattail		[illegible]	[illegible]	
Leafy pondweed	[illegible]			
Lophotocarpus	[illegible]	[illegible]	[illegible]	[illegible]
Duck potato	[illegible]		[illegible]	
Rice cutgrass	[illegible]	[illegible]	[illegible]	
Cyperus	[illegible]	[illegible]	[illegible]	
[illegible]		[illegible]		
Spike rush			[illegible]	
Coontail	[illegible]			
White water lily			[illegible]	
American lotus	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	

growing season. Pool 25 was never as productive in submergent growth as Pool 26, but when water levels were stable, as in 1948, 1949, 1953, and 1961, submergent aquatics did occur. After 1968, submerged aquatic growth was greatly reduced. This was the result of 2 consecutive years of severe water fluctuation and increased sedimentation and turbidity. In their 1975 report Klein et al. (1975: 31-34) reported only occasional submergent plant growth on Pools 24, 25, and 26. George Peyton, refuge manager for the Calhoun unit, Mark Twain National Wildlife Refuge, reported (personal communication) that no submerged aquatics now occur in Swan Lake.

Moist soil plant production depends upon consistent low water levels which expose mud flats during a minimum of 70 days between mid-July and the end of September. At the Batchtown area good moist soil production, predominantly wild millet and smartweeds, occurred when water levels were low and stable as in 1950, 1952, 1953, and 1959. In 1955 water levels were initially dropped in Pool 25 by the Corps and then raised throughout the growing season. This resulted in the destruction of most moist soil production.

Marsh plants, as a group, can withstand greater water level fluctuation than other types of wetland plants (Bellrose et al., 1977: C-34). This was the case at Flat and Gilbert Lakes. By 1944, after two consecutive years of flooding, most of the moist soil and submerged aquatic plants had disappeared and only marsh smartweed at Flat Lake, arrowhead at Gilbert Lake, and American lotus continued in their former abundance. Yeager (1949: 55) mentions that most plants except duck potato had virtually disappeared from the Calhoun Point area by 1945. Marsh plants are affected by fluctuating water, but to a lesser extent than other wetland plants.

The nine-foot channel project initially expanded and stabilized low water levels on Pool 26. This was of benefit to most wetland vegetation as recorded by Yeager (1949: 54), Leopold (1939), and Bellrose (1941: 278). However, Pool 25 was subject to frequent and sometimes severe fluctuations by the Corps of Engineers (narrative reports, Mark

Twain National Wildlife Refuge Batchtown unit, 1946-1951, 1954, 1956, 1961, 1967) (personal communication, George Payton, 1977) which adversely affected the growth of wetland plants. Bellrose (unpublished) also reported that much fluctuation of the pool levels occurred during the growing season. It is recognized that there can be little control over pool stages when levels rise above normal, but at other times, pool level manipulation should take into account multiple-use decisions including the effect on vegetation and animal populations (Klein et al., 1975: 95).

<u>The Effects of Sedimentation and Turbidity</u>. Since 1939 yearly changes occurred in the production of wetland plant communities on Pools 26 and 25 of the Illinois and Mississippi Rivers. These short-term changes were a result of water fluctuations attributed to either manipulation of pool levels by the Corps of Engineers or natural flood and drought conditions (see previous section). During the late 1960's the long-term effects of sedimentation and turbidity drastically affected marsh, submerged aquatic, and floating aquatic plants. Sedimentation and turbidity have always occurred in the Mississippi and Illinois River valleys, but in recent decades sedimentation has greatly increased for three major reasons: (1) a dramatic increase in row crops since the 1940's has resulted in greater rates of erosion, (2) navigation dams reduced the velocity of the current, reducing the river's ability to carry suspended sediment, and (3) the navigation channel permitted more barge traffic which increased turbidity by disturbing bottom sediments and coupled with increased recreational traffic greater bank erosion.

Turbidity affects wetland plant communities in several ways. The turbidity of water is attributable to suspended and colloidal matter, the effect of which is to reduce clearness and diminish the penetration of light (McKee and Wolf, 1963: 290). The greatest effect of turbidity is to reduce the amount of sunlight reaching photosynthesizing plants. This effect is most severe during the early growing season for both submerged and emergent plants (Low and Bellrose, 1944: 17). Similar

relationships between turbidity and aquatic plant production have been reported by other researchers (Martin and Uhler, 1939: 120; Chamberlain, 1948: 352; Robel, 1961: 437).

Other factors have been responsible for increasing turbidity in the Illinois and Mississippi Rivers. Waves produced by wind can resuspend bottom sediments and increase turbidity (Chamberlain, 1948: 342; Jackson and Starrett, 1959: 163). Jackson and Starrett reported that as wind velocity increased from 8 to 35 miles per hour at Lake Chautauqua (LaGrange Pool, Illinois River), the Jackson Turbidimeter Units increased from 174 to 700. Rough fish, primarily carp, disturb the false or soft mud bottom while feeding and cause sediment particles to become resuspended, thereby increasing the turbidity of backwater lakes and sloughs (Martin and Uhler, 1939: 120; Chamberlain, 1948: 353; Jackson and Starrett, 1959: 163).

It can be seen that several factors are responsible for the increase in turbidity of the Mississippi and Illinois Rivers. The end result has been to restrict the amount of sunlight reaching the bottom -- sunlight needed by plants to germinate and manufacture food.

Increased sedimentation has reduced the abundance of marsh and submerged aquatic plants in both Pools 25 and 26. Sedimentation produces a soft, false bottom which covers the original firm substrate, making it difficult for marsh and aquatic plants to gain or retain a foothold. Wave action uproots insecurely anchored vegetation as well as increases the water's turbidity. Sedimentation also affects aquatic and marsh plants by smothering valuable plant beds and partially filling backwater lakes and sloughs in the Illinois and Mississippi River valleys. Yeager (1949: 55) indicated that extreme flood conditions during the early growing seasons of 1943, 1944, and 1945 smothered submerged and emergent plant beds with mud, decreasing the stands of these plants in sloughs and lakes at Calhoun Point, Pool 26. As a result of sedimentation filling the backwater lakes and sloughs, the acreage of water is reduced and the bottom of the lakes becomes more uniform in depth, thereby decreasing species diversity of the plant community.

During the summer and fall, mud flats are often present on backwater lakes and sloughs of the Illinois and Mississippi Rivers. Before the nine-foot channel project, only limited acreage of mud flats occurred. Although these mud flats were inundated by the rising water levels created by implementation of the navigation channel, shallow areas surrounding bottomland lakes and sloughs have increasingly filled with silt. This process has destroyed productive marsh areas, but has recreated mud flats available for moist soil food production. The acres of mud flats now exceed the number present before the nine-foot project.

The nine-foot channel project initially created more water areas and stabilized low-water fluctuations which were beneficial to aquatic plant communities and subsequently fish and wildlife. Tables 35 and 36 list the acres and species of plants recorded by Dr. Frank Bellrose from 1941 to 1944 for Flat and Gilbert Lakes (Pool 26) which are located at the confluence of the Illinois and Mississippi Rivers. This area is indicative of the productive areas created by the expansion and stabilization of water levels in Pool 26. As a result of increased turbidity and sedimentation, the biological productivity of these areas has been reduced since the creation of Pool 26. Sedimentation was first mentioned as being a problem by a refuge manager as early as 1947, when it was suggested that Swan Lake (Pool 26) be protected by dikes. By the late 1960's submerged aquatic plant production began to decline. After major floods in 1969 and 1970 these plants have nearly disappeared from the Calhoun and Batchtown units of the Mark Twain National Wildlife Refuge (narrative reports) in Pools 26 and 25. As a result of increasing sedimentation and turbidity, many productive areas which initially supported luxurious aquatic plant growth and provided habitat for fish and wildlife have been degraded.

Water Quality

Upper Mississippi River

Information on the physical and chemical limnology of the upper Mississippi River was obtained from various literature sources. Pre-construction water quality references included Bartow (1913), Galtsoff (1924), Weinhold et al. (1925), Buswell (1927), Wiebe (1927), Ellis (1931a and b), Culler (1934), and Ellis (1936). Post-construction data sources included: Platner (1946), Barnickol and Starrett (1951), Dorris (1958), Dorris et al. (1963), Dunham (1971), and Colbert et al. (1975). A quantitative comparison of pre- and post-construction water quality in the upper Mississippi River proved difficult in that most of the above studies covered only brief periods of time or presented data from widely scattered localities.

From about 1900, numerous water quality studies of Illinois streams have been conducted by the Illinois Natural History Survey, Illinois Water Survey, and the U.S. Public Health Service. The Illinois River has received most of the attention by these agencies. Discussion of the effects of municipal, industrial, and agricultural pollutants on the water quality of the Illinois River can be found elsewhere in this report.

Early studies of Illinois streams were prompted by deteriorating water quality due primarily to increasing municipal pollution. In a survey of stream pollution in Illinois in 1924, the Illinois Water Survey identified communities discharging domestic wastes into streams of the state (Weinhold et al., 1925). At that time, investigators found that 208 Illinois towns located on streams had sewers and 72 had treatment facilities; however, 136 of these communities were discharging some unpurified sewage into water-courses (Weinhold et al., 1925: 35). Of the communities with treatment works, Weinhold et al. (1925: 56) stated that a large percentage were "poorly kept up and doing little if any good." In a similar survey in 1927, Buswell (1927: 9) reported that 227 streamside towns had sewers and 108 had treatment works, an increase of 36 towns

with treatment since 1924. Table 40 shows the number of municipal and industrial sources of pollution within the major drainage basins in Illinois in 1927 as taken from Buswell (1927: 9). The data show that there were some 54 sources of municipal and industrial pollution along the Mississippi River from the Wisconsin border to the Illinois River mouth. This compares to 256 combined sources in the Illinois River drainage basin (exclusive of the Metropolitan Sanitary District).

In a 1944 survey of the Mississippi River from Hastings, Minnesota (Mississippi River mile 814.0) to Caruthersville, Missouri (110 miles below Ohio River mouth), Platner (1946: 71) reported that

> the sum of all polluting effluents now entering the Mississippi River in the sector studies, are not creating conditions seriously unfavorable to fish and other aquatic life, except in local areas below particular plants or cities.

The following discussion of pre- and post-construction water quality parameters is broken down into four categories: (1) dissolved oxygen, (2) turbidity, suspended sediment, and water clarity, (3) nutrients, and (4) heavy metals and pesticides.

Dissolved Oxygen. In the early days of assessing water quality, investigators felt that the degree of municipal sewage pollution was best indicated by dissolved oxygen concentrations of receiving waters. Therefore, water quality data collected and presented during the preconstruction period were primarily dissolved oxygen levels and/or dissolved oxygen saturation values. In a comparison of the dissolved oxygen values in the Mississippi and Illinois Rivers near Grafton, Illinois (Mississippi River mile 218.5) in 1900, A.W. Palmer (Bartow, 1913: 32) found that the percentage of saturation averaged 76.5 percent (range 2-7 mg/l O_2) in the Illinois River, while a parallel series of samples from the Mississippi River averaged 82 percent (range, 3-8 mg/l O_2).

In 1926, the U.S. Bureau of Fisheries evaluated the effects of municipal pollution from the St. Paul-Minneapolis, Minnesota area (Mississippi River mile 851.0) on water quality in that reach of the Mississippi

Table 40

Number of Municipal and Industrial Sources of Pollution in the Major Drainage Basins of Illinois in 1927

Drainage Basin	No. of Towns Having Sewers	No. of Towns with Treatment Part. or Complete	No. of Industries Producing Pollution[a] Organic	No. of Industries Producing Pollution[a] Inorganic
Rock	20	6	55	34
Fox	18	12	12	11
DesPlaines and Illinois A[b]	33	21	18	26
Illinois B[c]	27	13	25	58
Illinois C[d]	10	5	12	8
Vermilion (Illinois)	3	1	6	8
Iroquois and Kankakee	11	4	12	4
Mackinaw	4	1	12	4
Sangamon	15	4	23	87
Vermilion(Wabash)	5	3	13	21
Kaskaskia	16	8	46	102
Little Wabash	7	4	6	0
Embarras	8	2	4	7
Big Muddy	13	9	13	102
Saline	3	2	3	33
Mississippi A[e]	5	1	10	8
Mississippi B[f]	5	4	7	2
Mississippi C[g]	3	0	5	4
Mississippi D[h]	11	3	15	35
Ohio	5	2	4	2
Wabash	5	3	9	5
Totals	227	108	305	559

Source: Buswell, 1927: 9.

[a]Exclusive of the Metropolitan Sanitary District of Chicago.

[b]Upper Illinois River to Vermilion River mouth.

[c]Vermilion River mouth to Sangamon River mouth.

[d]Sangamon River mouth to Illinois River mouth.

[e]Wisconsin border to Moline, Illinois.

[f]Moline, Illinois to Hamilton, Illinois.

[g]Hamilton, Illinois to Illinois River mouth.

[h]Illinois River mouth to Ohio River mouth.

River (Wiebe, 1927). During August and September, 1926, the dissolved oxygen content of the Mississippi ranged from 60 to 90 percent saturation above the Twin Cities, but was greatly reduced (4 to 50 percent) for several miles below that metropolitan area (Wiebe, 1927: 143).

The first extensive limnological survey of the upper Mississippi River was made by the U.S. Bureau of Fisheries in 1921 (Galtsoff, 1924). The survey was conducted on a 455-mile segment of the Mississippi from Hastings, Minnesota (Mississippi River mile 814.0) to Alexandria, Missouri (Mississippi River mile 359.0). Primarily concerned with the composition, amount, and distribution of plankton in the river, the survey party also collected data on discharge, suspended sediment, water clarity, and water temperature. Unfortunately, dissolved oxygen levels were not determined, leaving a void of information on this parameter for the period just prior to construction of the nine-foot navigation system.

In 1944, after construction of the nine-foot navigation system, the U.S. Fish and Wildlife Service conducted water quality studies of the Mississippi River from Hastings, Minnesota to Caruthersville, Missouri (Platner, 1946). The mean oxygen content of the Mississippi during a period of low water was 5.0 mg/l; in high water it averaged 7.6 mg/l; and in midwinter, 13.6 mg/l (Platner, 1946: 74). In summing up the general water quality of the Mississippi in 1944, Platner (1946: 72) stated: "Comparing the water quality of the Mississippi River with waters producing good fish fauna, it would be rated as good."

Dorris et al. (1963: 85) also reported seasonal differences in dissolved oxygen levels in their 1955 investigations on the Mississippi River near Quincy, Illinois (Mississippi River mile 325.0). They reported a mean winter dissolved oxygen of 11.2 mg/l and a mean summer dissolved oxygen of 6.8 mg/l (Dorris et al., 1963: 85).

Recent (1974) dissolved oxygen data for Pools 24, 25, and 26 were obtained from Colbert et al. (1975). These investigators also found seasonal fluctuations in dissolved oxygen concentrations. In a variety of aquatic habitats which included the main channel, side channels, dikes, and river border areas, Colbert et al. (1975: Table 6) reported

a July mean of 6.6 mg/l during a high river stage and a September mean of 9.3 mg/l during an average river stage. They found that dissolved oxygen saturation values were generally lower in all habitats during July and complete oxygen saturation was observed only during September (Colbert et al., 1975: 35). No dissolved oxygen concentrations during 1974 fell below the minimum Illinois and Missouri stream standard of 5 mg/l (Colbert et al., 1975: 35).

From a comparison of available pre- and post-construction dissolved oxygen data, it appears that the nine-foot navigation system has had no measurable effect on this water parameter.

Turbidity, Suspended Sediment, and Water Clarity. McKee and Wolf (1963: 290) stated that the turbidity of water is attributable to suspended and colloidal matter, the effect of which is to reduce clearness and diminish the penetration of light. Bellrose et al. (1977: C-42) reported that agricultural pollution (soil runoff) was probably the greatest factor contributing to high turbidity levels in the Illinois River. Other factors listed were resuspension of bottom sediments by barge traffic, bank erosion from boat-produced wakes and wind-produced waves, and feeding activities of fish (Bellrose et al., 1977: C-42). The greatest effect of high turbidity levels in freshwater systems is the restriction of sunlight needed for photosynthesis by aquatic plants. The effects of turbidity on aquatic plant production have been well documented (Martin and Uhler, 1939: 120; Low and Bellrose, 1944: 17; Chamberlain, 1948: 352; Robel, 1961: 437, and Bellrose et al., 1977: C-43).

Hooker (1897 in Galtsoff, 1924: 371) reported that suspended sediment (surface) levels in the period 1880-1881 in the upper Mississippi River from Winona, Minnesota (Mississippi River mile 725.0) to Hannibal, Missouri (Mississippi River mile 309.0) ranged from 34 to 165 ppm, with increasing levels downstream. Hooker found that at St. Louis (Mississippi River mile 180.0) the suspended sediment concentration was 686 ppm, which he attributed to the influence of the Missouri River; in 1879, the Missouri River contained 2,418 ppm sediment

at its mouth near St. Charles, Missouri (Mississippi River mile 195.0) (Hooker, 1897, in Galtsoff, 1924: 371). The influence of the highly turbid waters of the Missouri River on the lower Mississippi River was also noted by Townsend (1915 in Galtsoff, 1924: 370);

> The amount of sediment in the lower Mississippi depends almost exclusively on the proportion of water from the Missouri. In comparison with the Missouri, the upper Mississippi is a clear stream and the amount of sediment carried by it is insignificant.

Water clarity is influenced by factors other than suspended sediemnt, such as the quantity of plankton. However, Galtsoff (1924: 372) felt that in the Mississippi River, water transparency depended principally on the amount of sediment in suspension. He reported that the upper Mississippi in 1921 was "muddy" even during low water and progressively more turbid downstream (Galtsoff, 1924: 371). Water clarity readings (measured by a round white disk, 25 cm diameter) during the 1921 survey ranged from a maximum of 10[illegible] cm at the outlet of Lake Pepin (Mississippi River mile 763.5) to 22 cm at Fairport, Iowa (Mississippi River mile 463.0) (Galtsoff, 1924: 371).

Platner (1946: 16) also reported an increase of turbidity in a downstream direction in the Mississippi River. His only comments on the methods he used were: " . . . turbidity was recorded in parts per million based on readings calculated from a previously standardized Fuller's earth curve" (1946: 16) and "The percentage of sedimentation was recorded in a 100 ml capacity mine-waste tube, one hour after collection of the sample" (1946: 16). He found average turbidity values during low water at 40 ppm in the upper reaches of the river, 300 ppm in a middle section, and 1,880 ppm below the mouth of the Missouri River (Platner, 1946: 16). Both Galtsoff (1924: 371) and Platner (1946: 16) noted that turbidity levels increased with an increase in river water levels. Turbidity levels during high water averaged 40 percent greater than during low water (Platner, 1946: 16).

In 1955, Dorris _et al_. (1963) sampled several limnological parameters

of the Mississippi River near Quincy, Illinois (Mississippi River mile 325.0). Light penetration was measured by using a Jackson turbidimeter and averaged 38 cm for the year (Dorris et al., 1963: 84). Dorris et al. (1963: 84) also found a relationship between stream discharge and light penetration. High stream discharge rates were accompanied by low light penetration and low photosynthesis. High turbidity appeared to be caused by silt loading, rather than by plankton, since photosynthetic oxygen production almost always decreased at the time of high turbidity (Dorris et al., 1963: 84).

Recent turbidity data for Pools 24, 25, and 26 were found in Dunham (1971: Table 10) and Colbert et al. (1975: Table 6). Dunham (1971: Table 10) measured tailwater turbidities below Locks and Dams 12-26 in 1971. He found that water clarity (Secchi disk) during low water decreased downstream from a high of 20 cm below Lock and Dam 12 to a low of 10 cm below Lock and Dam 26 (Dunham, 1971: Table 10). Colbert et al. (1975: 32) measured turbidity photometrically with a Hach Model DREL laboratory kit, using a Hach absorptometric method. Turbidity values for Pools 24, 25, and 26 in 1974 were directly related to current velocity (Colbert et al., 1975: 36), and mean values at the surface were 257.4 units during high water in July and 46.2 units during low water in September (Colbert et al., 1975: Table 6). Settleable solids, measured volumetrically with a 1-liter Imhoff cone using standard methods, followed the same pattern (Colbert et al., 1975: 22, Table 6).

Regarding the quantity of erosion silt in the Mississippi River, Ellis (1931b: 5) wrote:

> The most outstanding factor producing changes in river conditions at present (1930) throughout the Mississippi system was found to be erosion silt. As a result of deforestation, current methods of tilling the land, and various improvements incident to commercial progress as road building, the amount of erosion silt which is being received by the various streams of the Mississippi system has been progressively greater during the past 10 years until it now presents perhaps the most acute fisheries problem in our inland rivers.

Nutrients (Ammonia-nitrogen, Nitrate-nitrogen, Nitrite-nitrogen, and Total Phosphorus). An extensive literature search yielded very little information on pre-construction nutrient levels in the upper Mississippi River. Clarke (1908, in Galtsoff, 1921: 371) reported nitrate-nitrogen concentrations of 0.85 ppm at Minneapolis, Minnesota (Mississippi River mile 850) and 0.10 ppm at Memphis, Tennessee in 1906-1907. In 1921, McHargue and Peter (1921, in Platner, 1946: 5) found that nitrate-nitrogen was absent in samples at Minneapolis, but occurred at Baton Rouge, Louisiana. Ammonia-nitrogen apparently occurred only in the Baton Rouge samples (McHargue and Peter, 1921, in Platner, 1946: 5).

Platner (1946: 74), in his 1944 water quality survey of the upper Mississippi River, found that total nitrogen values were less than 1.0 ppm in midwinter, averaged 1.7 ppm during low water and 1.5 ppm in high water. The 1944 phosphate levels of the Mississippi River ranged from .05 to .22 ppm during midwinter, .20 to .35 ppm during high water, and .22 to .45 during low water (Platner, 1946: Figure 13).

Colbert et al. (1975: 39) reported that 1974 nutrient concentrations in Pools 24, 25, and 26 were comparable to those found by Platner (1946) in 1944. Nutrient concentrations in 1974 were higher during a high stage than during an average stage (Colbert et al., 1975: 38). This was also observed by Platner (1946: 74). Ammonia-nitrogen levels (main channel) in Pools 24, 25, and 26 in 1974 averaged 0.12 mg/l during an average stage and 0.70 mg/l at a high stage (Colbert et al., 1975: D-3). Total phosphorus levels the same year averaged 0.18 mg/l and 1.2 mg/l during average and high stages, respectively (Colbert et al., 1974: D-3). Colbert et al. (1975: 38) attributed the increase in nutrient concentrations during high water to the resuspension of nutrients from bottom sediments and to land runoff.

Due to lack of early data, it was impossible to evaluate pre- and post-construction changes of nutrient concentrations in the upper Mississippi River.

Heavy Metals and Pesticides. The analytical methodology to measure trace materials in water was in its infancy in the period preceding construction of the nine-foot navigation system. Therefore, no data on heavy metals or pesticides were obtained for this period.

A few trace elements (iron, manganese, zinc, and fluorine) were measured by Platner (1946). Recent (1974) heavy metal data for Pools

24, 25, and 26 can be found in Colbert et al. (1975).

In general, one would expect the concentration of toxic materials in sediments to increase in the downstream direction in each pool, due to the physical distribution of sediment according to particle size and weight. For the same reasons, one would also expect a lateral distribution, with higher concentrations in slackwater areas than in the main channel. Small particles of clay and organic matter have both a greater affinity for toxicants than larger particles such as sand, and also a much greater surface area per unit weight. The finer particles settle out where the current velocity is reduced: above the dams and in areas lateral to the main channel, hence one would expect the concentration of toxicants in sediment to follow the same distribution.

Illinois River

We were able to find very little water quality data collected before 1930 on the lower 80 miles of the Illinois River. Most of the early water quality studies by the Illinois Natural History Survey and Illinois State Water Survey were directed toward measuring the degree and extent of pollution in the middle and upper reaches of the Illinois River. Richardson (1921b) states that by 1920, the bottom fauna in the river and bottomland lakes as far downstream as Browning (mile 57.0) had been affected by organic waste and low dissolved oxygen levels. His statement indicates that the lower river either was not affected, or affected to a lesser degree than the middle and upper reaches of the river.

The section on benthos in the Illinois River described how the tubificid worms, fingernail clams, and chironomid larvae increased between 1915 and 1964. These results indicate that the organic loading of the lower river may have increased, while the dissolved oxygen levels had declined slightly. Figure 8 shows that a pronounced oxygen sag occurred in the La Grange Pool, immediately upstream from the study reach. The water was reaerated as it flowed over the La Grange Dam, and then a slight sag occurred in the lower 80 miles of the

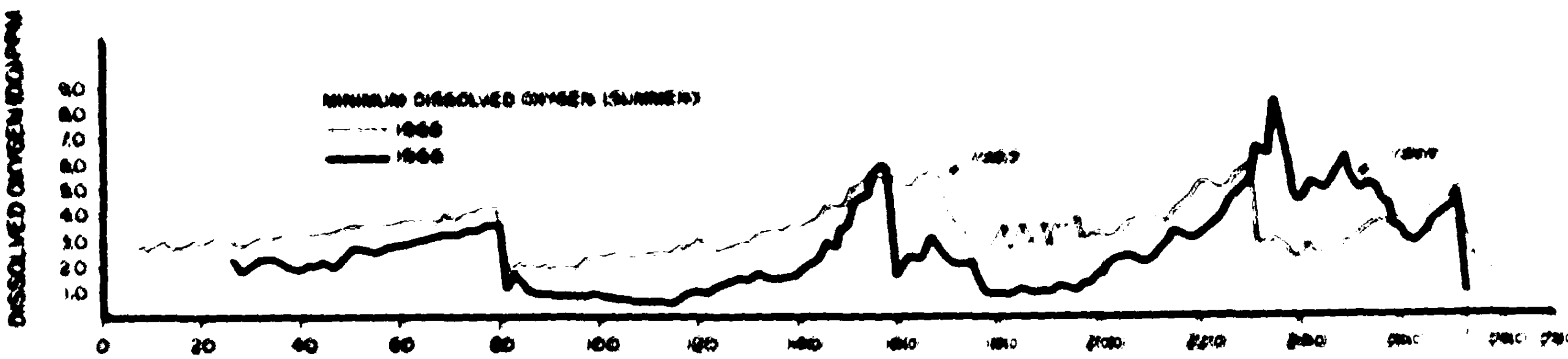


Figure 8. Average dissolved oxygen concentrations in the main channel of the Illinois River in July and August, 1965-1966. Measurements were made prior to sunrise, when the oxygen levels were at the daily minimum.

Illinois River. The minimum dissolved oxygen levels in the study reach in 1965-66 were 2-3 mg/l (Figure 8) -- lower than the current Illinois standard of 4.0 mg/l, and probably low enough to stress some types of aquatic organisms. Recent data indicate that dissolved oxygen levels in the backwaters and lakes have declined, probably due to the high oxygen demand exerted by the sediments, while the oxygen levels in the river have improved. Studies conducted in the summer of 1977 by the Illinois Natural History Survey at river mile 99 (which is probably representative of conditions in the study area, although it is located upstream from the La Grange Lock and Dam) showed that the minimum dissolved oxygen level in water coming out of a backwater through Panther Slough was a few tenths of a ppm, while dissolved oxygen levels at the same time in the main channel were on the order of 5-6 ppm.

The benthos section of this report showed that the numbers of oligochaete worms, midges, and perhaps fingernail clams declined between 1964 and 1974-75, possibly indicating a reduction in the organic load of the river and improvement in the dissolved oxygen levels. The increase in number of mayflies from 4 per square meter in 1964 to 172.2 per square meter in 1975 also indicates an improvement in dissolved oxygen levels.

The disappearance of snails in the lower Illinois River between 1964 and 1975 may indicate a toxicity problem, and pesticides were implicated in studies where caged snails rapidly accumulated dieldrin when placed in the Illinois River (see the benthos section). The demise of vascular aquatic vegetation in the lower Illinois River in the late 1950's may be attributable to increasing turbidity which reduces the penetration of light needed for photosynthesis, or to a toxicity problem. Colbert et al. (1975: 42-43, Table D-11) found that iron concentrations in the water at all stations except one exceeded the 1.0 mg/l Illinois standard, and mercury concentrations at most stations exceeded the 0.0005 mg/l Illinois standard. The only factor which differed between the Illinois and Mississippi Rivers within the study area was total phosphorus, which was highest in the Illinois River. Colbert et al. (1975: 46-47)

reported that the sediments of the lower Illinois River contained higher concentrations of ammonia, phosphorus, and iron than sediment in the Mississippi River. Mean PCB and pesticide concentrations in the sediments of the side channels were comparable for both rivers. Sediment in the main channel of the Illinois River contained detectable pesticide concentrations, whereas the Mississippi River did not. Slightly higher PCB concentrations also occurred in the sediments of the main channel of the Illinois River.

Sediment

Sediment has many effects on aquatic ecosystems in the Mississippi and Illinois River valleys. Sediment can occur in an aquatic ecosystem in several ways. Suspended sediment is that particulate matter that is carried in the water column. Deposited sediment is that particulate matter that has dropped from the water column. Resuspended sediment is stirred up from the bottom by water currents, wave action, boat traffic, or by the rooting activities of fish, such as carp. Sedimentation is defined as the deposition of the solid particulate material by water.

When sediment is suspended or resuspended in the water column it contributes to turbidity. In the case of the lower Illinois River valley, the sediments have formed a soft or false bottom that is readily resuspended.

From Keokuk, Iowa south to Alton, Illinois, the bottom of the Mississippi River is dominated by sand which is mixed with silt in some locations (Platner, 1946: Table 5). This type of bottom is less easily resuspended than the Illinois River bottom.

The Mississippi has been historically described as carrying a large silt load (Saxon, 1927: 78; Galtsoff, 1923: 371). The Illinois River, on the contrary, was relatively clear. Barrows (1910: 4) described the original discharge of the Illinois River as relatively small, being less than the Rock River and a small fraction of the Mississippi. The Illinois flows in an unusually wide floodplain and drops sediment on its sluggish edges resulting in the formation of natural lateral levees and bottomland lakes (Mills, Starrett, and Bellrose, 1966: 3). The Mississippi flows at a higher velocity but also forms natural levees, although these levees are somewhat smaller than those on the Illinois River (Rubey, 1952: 123).

Two major changes have occurred in the lower Illinois and Mississippi valleys. The first major change took place mainly in the first quarter of this century, when large tracts of bottomland were drained and leveed from the rivers. In the Illinois River valley, approximately half of

the bottomland acres were drained (Mills, Starrett, and Bellrose, 1966: 5). The second major alteration was the implementation of the nine-foot channel. By comparing mean water levels before and after the nine-foot channel project at dams 24, 25, and 26, the increase in water levels was found to be approximately 9, 10, and 9 feet respectively.

As a result of man's activities, the rate of sedimentation and the turbidity have increased since the 1900's. The apparent main factor responsible for this increase has been the expansion of row crop production. Construction of the locks and dams and municipal sewage effluents have compounded this problem. These activities have changed the clarity of the river and the nature of the bottomland lakes in the Illinois and Mississippi Rivers. Detailed studies to determine what percent of sediment results from agricultural erosion and what percent from construction of the dams have never been undertaken.

An increase in the turbidity of the Illinois River can be demonstrated by comparing data collected by Kofoid in 1903 and the Illinois Natural History Survey in 1974 and 1976. Kofoid (1903: 179) used a white porcelain plate to determine that the majority of transparencies in the Havana, Illinois area were between 8 and 20 inches. He stated that during floods, the water was turbid; however, the water cleared following its decline. In 1974, the majority of Secchi disk readings taken in the Alton Pool, Illinois River, were between 7 and 9 inches. Bottomland lakes located in the middle Illinois River valley were more turbid; the majority of readings collected by the authors in 1976 were between 4 and 7 inches.

A three-fold increase in Jackson Turbidimeter Units (JTU's) taken under similar conditions between 1897 and 1964 occurred in the La Grange Pool, Illinois River (Mills, Starrett, and Bellrose, 1966: 7). A comparison of JTU's taken at Lake Chautauqua in 1955 (Jackson and Starrett, 1959: 13) with JTU's obtained in 1977 under analogous conditions indicates an almost two-fold increase. Although these data are from La Grange Pool, the increase in turbidity at Lake Chautauqua is indicative of the general change that occurred in the bottomland lakes of the Illinois River.

There were few turbidity measurements in the Mississippi River. In July, 1921 Galtsoff (1923: 372) measured a transparency of 61 cm near Montrose, Iowa. The Illinois Natural History Survey recorded transparencies

of 27 and 40 cm in the same location in late June, 1974 and 1975. The scant data available indicate that turbidity has increased in the Mississippi River, although this increase is not as great as in the Illinois River.

Several factors have been responsible for the increased sedimentation rate. The dramatic intensification in agrarian practices since the middle 1800's has greatly increased soil pollution in the Illinois and Mississippi River valleys. Clearing of fencerows and bottomland timber in addition to emphasis on row crop production have created serious erosion problems. In 1886 Illinois farmers planted nearly 6 million acres of row crops (Aldrich, 1965), approximately 17 percent of the state. The number of acres increased to over 10 million by the early 1900's (Aldrich, 1965: 12) or 28% of the state planted in row crops. A slight increase to 33.3% was calculated from the Illinois Cooperative Crop Reporting Service annual summary in 1945. A jump to 50.6 percent was calculated in 1974 and 54.8 in 1976. When using 52 counties in the state which drain completely or partially into the Illinois River, a similar increase is found. In 1945 41.1 percent of these counties were planted in row crops. By 1974 this figure had jumped to 57.8 percent and increased by 3.7 percent in just two years to 61.5 percent in 1976.

We have no data to illustrate this change on the Mississippi drainage system, but Barnickol and Starrett (1951: 274) indicate that soil pollution has long been associated with the Mississippi below the mouth of the Missouri, but it was not generally noted in the upper part of the river until after the development of intensive farming in the Middle West. The drainage of bottomland lakes and marshes and the channelization of tributaries have increased the amount of sediment entering the rivers.

Sedimentation rates are influenced by several factors among which are water flow, seasonal variability of the flow, sediment load, character of the sediment, and geometry of the system. Although all of these factors play a role in sedimentation, there is a high correlation between sedimentation rates and water depth in the backwater lakes of the Illinois River. Deep water areas of these lakes show higher sedimentation rates than those with shallower waters. The constant reduction in depth as a

result of sedimentation must be taken into account if sedimentation rates are compared over a period of time. By graphing the rate of fill at each location against its original depth, the effect of changing depths is negated, allowing a direct comparison of sedimentation rates.

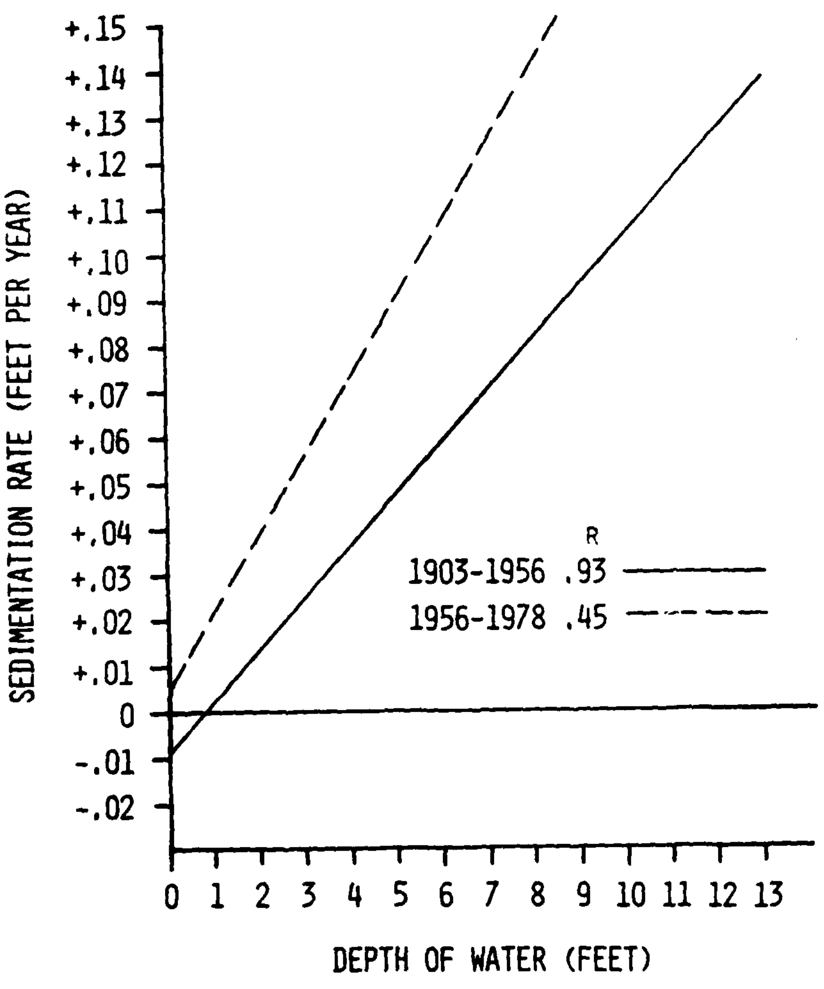
Sedimentation studies made at Lake Meredosia reveal the importance of changing depths when comparing sedimentation rates over a large number of years. A direct comparison of gross average fill per year at Lake Meredosia for the periods 1903-1956 and 1956-1978 was .043 ft./year and .042 ft./year respectively. This would seem to indicate that the sedimentation rates are nearly equal. By plotting the rate of sedimentation against the depth (Figure 9) and comparing the location of the regression lines, an increase in the sedimentation rate can be seen. Although the sediment load of the water has increased, unless the effect of changing depths is taken into account, the sedimentation rates cannot be directly compared over a long period of time.

The streams that flow into the Illinois have a steeper gradient than does the Illinois in its central and lower reaches (Mills, Starrett, and Bellrose, 1966: 5). As a result of its low gradient and slow current velocity, the Illinois River deposits silt in the bottomland lakes during high water. The effect of drainage has been to reduce the area in which silt can be deposited, thereby increasing the amount of silt in the river and remaining bottomland lakes.

The construction of the navigation dams on the Illinois and Mississippi Rivers slowed the current, compounding this problem. Forbes and Richardson (1920: xi, xli) reported that the Illinois River's usual rate of flow for ordinary stages varied from 1½ to 2½ miles per hour. As a result of higher dams associated with the nine-foot channel and reduced diversion from Lake Michigan, the current velocity is now only about 0.6 miles per hour at ordinary stages.

Solomon et al. (1975: 67) indicate that on the Mississippi at low and intermediate river flows, pool levels are held above the natural level by the dams, resulting in decreased flow velocity. Carlander (1954: 21) also indicated the current in most of the Mississippi River from St. Paul, Minnesota to Alton, Illinois had been greatly reduced

Figure 9. The yearly rate of sedimentation at Meredosia Bay determined for two periods, 1903-1956 and 1956-1978.



because of the dams. This decrease in the Mississippi and Illinois Rivers' current velocity has reduced their silt-carrying capacity, increasing the siltation problem.

Increased water levels created by the construction of the dams also increased sedimentation rates. This statement is supported by the fact that the sedimetation rate in Lake Meredosia increased as its depth became greater. This has been further illustrated for eight lakes in the middle Illinois valley (Bellrose et al., 1977: C-11, C-15). The construction of the dams increased water levels at Clarksville, Missouri, Cap Au Gris, Missouri, and Grafton, Illinois approximately 9, 10, and 9 feet, respectively. These water depths were greatest just above the dams and diminished as the distance upstream from the dams increased (Simons, 1975: 94). The increased water levels in the channel and backwater areas created by the construction of the dams, combined with a reduction in current velocity, increased the rate of sedimentation.

Barge traffic, associated with the impoundment of the navigation channel, increases suspended sediments in two ways: (1) Movement of the barges and the associated towboat causes a strong current on the silt bottom, which resuspends the silt particles, thereby increasing turbidity. (2) Bank erosion and resuspension of silt in shallow areas result from the wake produced by a passing barge. Starrett (1971: 273) observed an increased in suspended sediments on the Illinois River:

> On November 18, 1964 in the Alton Pool at river mile 65.1, the turbidity just prior to the passing of two towboats was 108 units and within 6 minutes after the tows had passed, the turbidity was 320 units. Sixteen minutes later the turbidity had dropped to 240 units.

Pools 24, 25, and 26 have complex networks of channels, pools, and backwater areas. Water is generally supplied to the backwater areas through runoff, and during high river stages, spillage occurs from the main channel to the backwater areas (Karaki and Van Hoften, 1974: 19).

Karaki and VanHoften (1974: 19) indicate that the sediment plume of towboats, shown in infrared photographs, spreads across the main channel and can be carried to backwater areas if there is a flow into these areas from the main stream. Another statement supporting lateral movement of resuspended sediments on the Illinois and Mississippi Rivers is a conclusion by Johnson (1976: 124):

> It was found that lateral movement of sediments resuspended by tows and transported from the main channel to shoreward areas, including potentially productive side channel areas, does occur during normal pool conditions.

Jackson turbidimeter readings of Lake Chautauqua, LaGrange Pool, taken in 1977, indicate that suspended sediments are transported into backwaters during high water (Table 41). These findings indicate that turbidity was greatest at a break in the levee at the southwest shore and decreased gradually toward the middle of the lake and away from the levee.

It is the authors' opinion that when the river is flowing into backwater lakes, passage of barge traffic will result in lateral transport of resuspended sediment into backwater lakes, resulting in an increased sedimentation rate.

The single greatest physical effect of increased sedimentation in the Illinois and Mississippi River valleys has been the acceleration of filling in backwater areas. The Illinois State Water Survey has found that backwater areas such as Meredosia in pool 26 are filling at relatively rapid rates. Lake Meredosia in 72 years lost 46% of its original storage capacity. The Water Survey calculated that the expected life of this lake is less than 100 years (Lee, Stall, and Butts, 1976: 7).

Sedimentation has adversely affected marsh and aquatic plants by creating a soft, false bottom and by filling shallow areas inhabited by these plants.

Our conclusions regarding the amount and effect of sedimentation in the study area conflict substantially with those drawn by Simons et al.

Table 41

Turbidity of Lake Chautauqua During High River Stages and 0-5 mph Wind on 10 May 1977

Distance from River Levee in Yards	Jackson Turbidimeter Units	Depth of Water in Feet and Inches
At levee	170	-
125	126	-
230	100	4' 9½"
410	66	5' 3½"
660	59	5' 7½"
985	60	6' 2½"
1295	67	6' 6"
1610	71	7' 8"
1960	72	6' 8"
2285	59	6' 7½"
2610	58	6' 4½"
2810 (200 yards off east shore)	57	-
2895 (115 yards off east shore)	42	5' 8"

(1975: 93-96). The conclusions differ because: (1) Simons et al. studied the movement of sand only, and (2) they studied sedimentation in the main channel only, not backwater areas which are the most important to fish and wildlife.

In the Simons study, they limited sediment transport to sand transport capacity (Simons et al., 1975: 26). They concluded that an increase of 3 percent occurred between 1929 and 1973 (Simons et al., 1975: 77). Our observations indicate that in backwater areas the deposition of silt rather than sand is the major constituent of sediment in the Mississippi and Illinois River valleys. Furthermore, turbidity of the water is the result of fine silt particles (Dorris, Copeland, and Lever, 1954: 84), whereas sand, which is a larger, heavier particle, is only suspended by fast-moving water.

Simons' conclusion as to the amount of sedimentation was derived from riverbed elevation changes only in the deepest 1,000-foot section of the channel (Simons, 1975: 62). These areas are subject to currents caused by towboats. In our studies on Peoria Lake in the middle Illinois valley, there are areas where the river channel is now deeper than in 1903 and adjacent areas, 100 feet from the channel, have filled in dramatically. As one moves from the main channel to lateral backwaters, the current diminishes, and the silt load is dropped. The backwater areas, where the greatest amount of sedimentation occurs, are also the most important areas for fish and wildlife. In these areas submerged aquatic and marsh plants, which provide food and habitat for fish and wildlife, have been reduced to mere remnants of what they once were (see aquatic vegetation section; Bellrose et al., 1976: C-19–C-46).

Simons' conclusion that "50 years from now the river scene in the study reach will be essentially as it is today" does not take into account these factors. Although the river channel may remain stable, the backwater areas are undergoing an accelerated rate of change. Succession has been increased to such an extent that changes that would normally take thousands of years are being completed in less than 150

years. Lakes Depue, Chautauqua, and Meredosia will be completely filled within 100 years according to the Illinois State Water Survey (Lee, 1976: 6; Lee, Stall, and Butts, 1976: 7). Increased sedimentation, primarily from agricultural intensification of land use, and turbidity have been major factors responsible for degrading backwater areas in Pools 24, 25, and 26 on the Mississippi River and Pool 26 on the Illinois River. Impounding Pools 24, 25, and 26 increased the water surface area, but in the ensuing years, sedimentation has filled in appreciable acreage that has returned to wooded vegetation.

Terrestrial Communities

Waterfowl

Pools 24, 25, and 26 are the most important navigation pools on the entire Mississippi River for the mallard, the most abundant duck in the Mississippi flyway. Pool 19 is the most important navigation pool for lesser scaups, and next to pool 8, also contains the largest concentration of canvasbacks in the Midwest.

Private duck clubs abound laterally to Pools 24-26, and are especially prevalent adjacent to Pool 26 in St. Charles County, Missouri. Extensive public shooting grounds occur in Pools 25 and 26, but only small areas are utilized for public hunting in Pool 24. Refuges have been established by the U.S. Fish and Wildlife Service in Pools 25 and 26, and adjacent to Pool 24.

Impounding the Mississippi River with navigation dams that created navigation Pools 24-26 generally enhanced waterfowl habitat by creating many thousands of acres of shallow water. The addition of refuges in the impoundments added greatly to the assets of the pools both for waterfowl occupancy and waterfowl hunting (Bellrose, 1954: 169).

Bellrose et al. (1977: C46) indicated that the abundance of various natural food plants in the Illinois River valley was correlated to the amount of time spent in the valley by certain species of waterfowl. The pintail showed an increase in density as the abundance of moist soil and marsh food plants increased. The vigeon's use of the valley correlated with increased aquatic plant production. Green-winged teal abundance increased as the abundance of all waterfowl food plants increased.

Moist soil plants currently constitute the majority of natural waterfowl foods in the project area. They volunteer on exposed mud flats during the summer and must be inundated by 0.5 to 1.5 feet of water in the fall to enable waterfowl to feed upon the seeds produced. Moist soil plants are especially sensitive to pool levels early in growth when inundation will drown them. Many of the duck clubs, federal

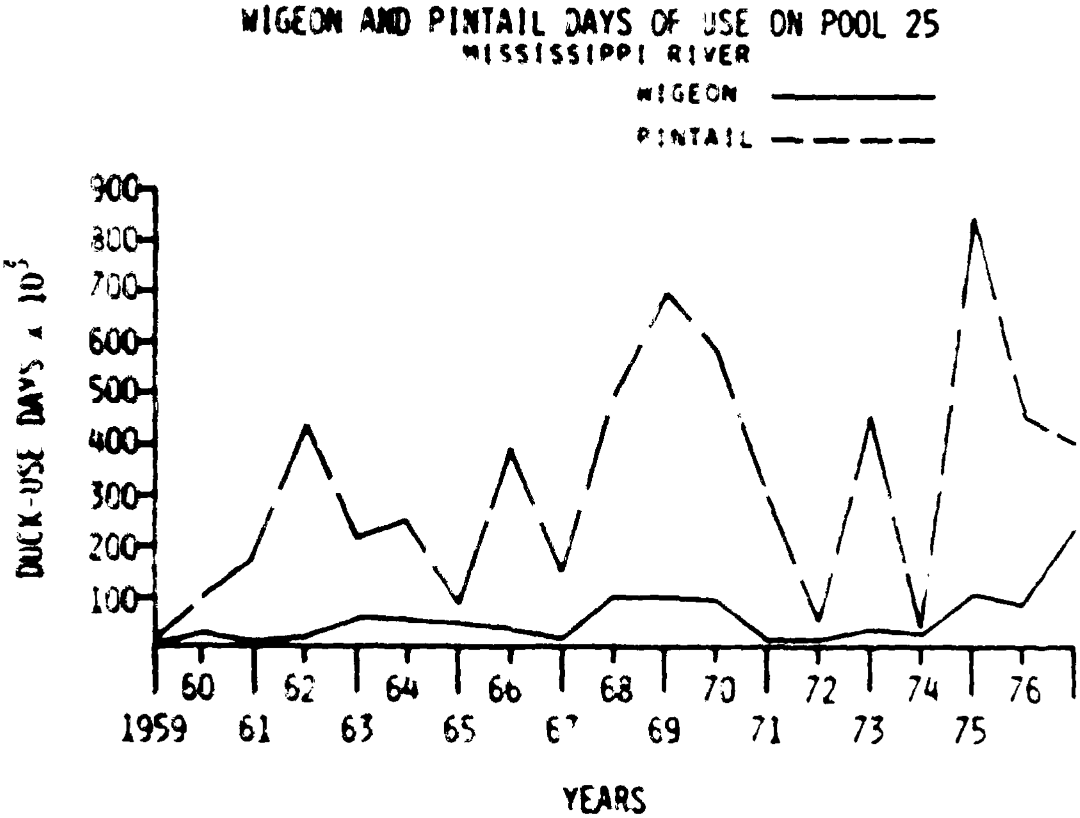
and state refuges have built low levees adjacent to the pools in which water levels can be artificially controlled. These areas are not affected by manipulation of pool levels unless the low levees are topped.

In non-leveed areas, the manipulation of pool levels, particularly on Pools 26 and 25, has an important bearing on their value for waterfowl. Levels that eliminate or reduce the growth of moist soil plants in mid-summer or do not flood them in the fall, reduce the use of these pools by waterfowl. Pool fluctuations resulting from floods are understandably beyond the control of pool management. However, other changes in pool levels appear to be within the ability of management to control.

Since 1939 the Army Corps of Engineers has manipulated water levels in the study area to maintain a nine-foot navigation channel. This manipulation resulted for the most part in stabilizing low water levels, which benefited waterfowl populations. However, when the water levels are dropped in the fall as a result of pool operations, moist soil and (under extreme drawdowns) submerged aquatic plants are left stranded on mud flats. This makes these food plants inaccessible to waterfowl. Narrative reports from the Calhoun and Batchtown divisions of Mark Twain National Wildlife Refuge indicate that drawdowns occurred during the summers of 1952, 1953, 1956, and 1959 at the Calhoun unit (Pool 26), and 1951, 1954, 1961, and 1972 at the Batchtown unit (Pool 25). Moreover, during the fall of 1956 and 1959 at the Calhoun unit and 1957 and 1961 at the Batchtown unit, drawdowns ranged from 2 feet to over 3 feet making it difficult or impossible for hunters to reach duck blinds. Waterfowl data for the 1950's were not complete but the effect of fall drawdown on waterfowl can be seen in Figure 10. The pintail and wigeon show a decline during the fall drawdowns of 1961 and 1972 on Pool 25. Narrative reports from the Calhoun and Batchtown units indicate that during the fall drawdowns of the 1950's, duck use of the refuges was reduced.

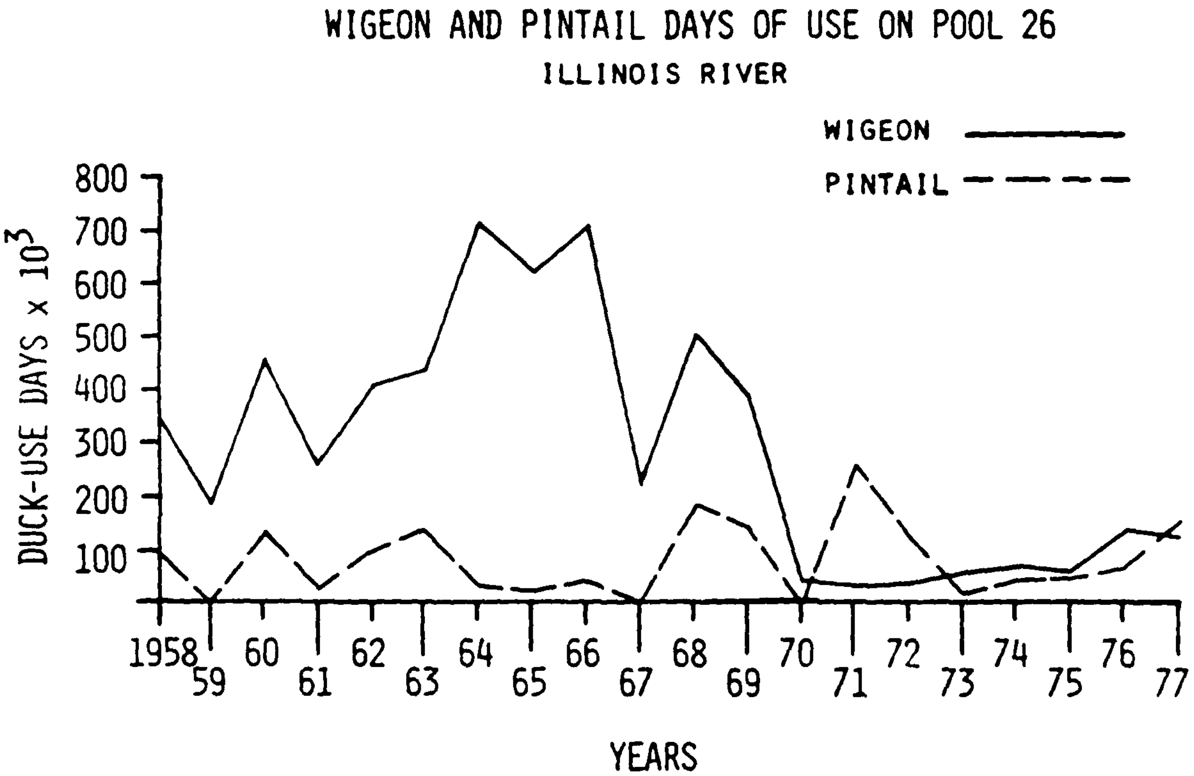
Increased sedimentation and concomitant turbidity have had a detrimental effect on waterfowl populations. As discussed previously in the wetland plant section, by 1970 increased sedimentation and turbidity resulted in a great reduction in submerged aquatic plants in the Calhoun Refuge. With this loss of plants, the wigeon and green-wing teal abundance plummeted on Pool 26 of the Illinois River. Figure 11

Figure 10.



WIGEON AND PINTAIL DAYS OF USE ON POOL 25
MISSISSIPPI RIVER
WIGEON
PINTAIL
DUCK-USE DAYS x 10^3
900
800
700
600
500
400
300
200
100
60
62
64
66
68
70
72
74
76
1959
61
63
65
69
71
73
75
YEARS

Figure 11.


WIGEON AND PINTAIL DAYS OF USE ON POOL 26
ILLINOIS RIVER
WIGEON
PINTAIL
DUCK-USE DAYS x 10^3
800
700
600
500
400
300
200
100
1958
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
YEARS

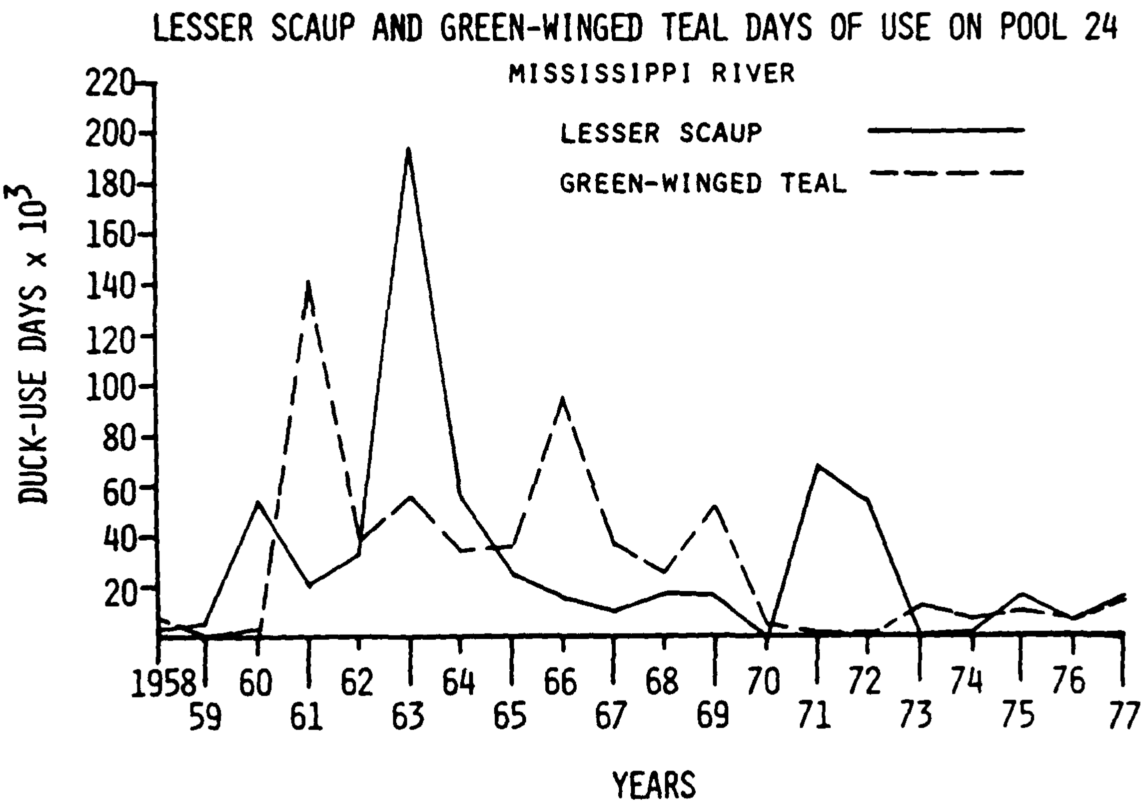
indicates that green-wing teal duck-days dropped from a high of 286,000 duck-days in 1963 to a low of 12,000 duck-days in 1970 while the wigeon fell gradually from a high 713,000 duck-days in 1964 to 43,000 in 1970. A slight increase in use has occurred during the past two years.

Lesser scaups have utilized Pools 25 and 26 more extensively than Pool 24. Scaup days of use (Figures 12, 13, & 14) have shown a downward trend throughout the period 1959-1977. The reason for this decline is not fully understood, but in the Illinois valley a decrease in food supplies resulted in a drastic decline in scaup abundance (Mills et al., 1966: 18). Anderson (1959: 317) found that lesser scaup fed on plant meterial 10 percent of the time in the upper Illinois River and in the Mississippi River above Pools 24, 25, and 26. The fingernail clam, a major food source of the lesser scaup, was found in greater abundance in these reaches of the two rivers than in the project area. Therefore, aquatic plants are probably more important to the lesser scaup diet in Pools 24, 25, and 26. The decrease of aquatic plants in the late 1960's would adversely affect the lesser scaup utilization of the project area.

The mallard has been the principal species benefited by the pool impoundments and refuges. Mallard use of Pools 24, 25, and 26 has been increasing in recent years (Figure 15). Although mallards are able to obtain a large share of their food from waste corn left in the fields after havvest, the increased water acreage is valuable as resting sites. The loss of aquatic plants affected mallards less than other species; they feed in shallow water primarily on seeds of moist soil plants. Federal and state agencies as well as numerous private duck clubs have developed low leveed areas for the development of moist soil waterfowl foods on areas adjacent to Pools 24-26. The presence of managed waterfowl areas lateral to the project area has increased mallard use in the project area.

The wood duck is the primary breeding duck in the project area. Natural cavities found in mature timber are used by the wood duck as nesting cavities. The clearing of extensive tracts of mature bottomland forest prior to impoundment reduced the number of natural cavities available for nesting. However, the increase in water levels

Figure 12.



LESSER SCAUP AND GREEN-WINGED TEAL DAYS OF USE ON POOL 24
MISSISSIPPI RIVER
LESSER SCAUP
GREEN-WINGED TEAL
DUCK-USE DAYS x 10^3
220
200
180
160
140
120
100
80
60
40
20
1958
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
YEARS

Figure 13.

LESSER SCAUP AND GREEN-WINGED TEAL DAYS OF USE ON POOL 25

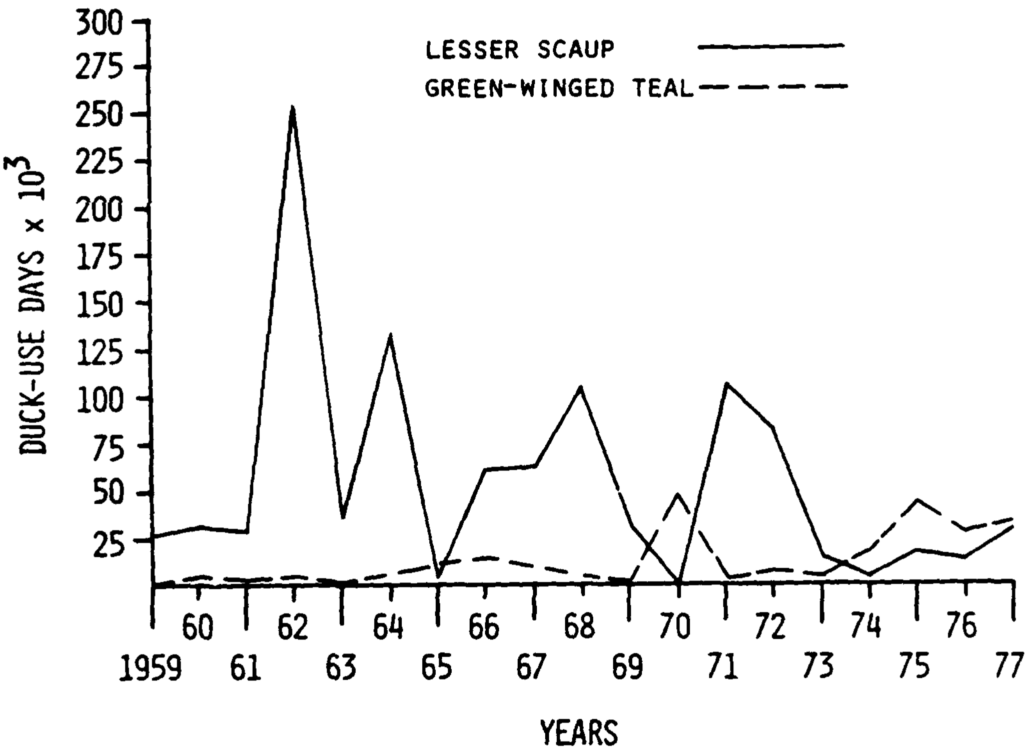
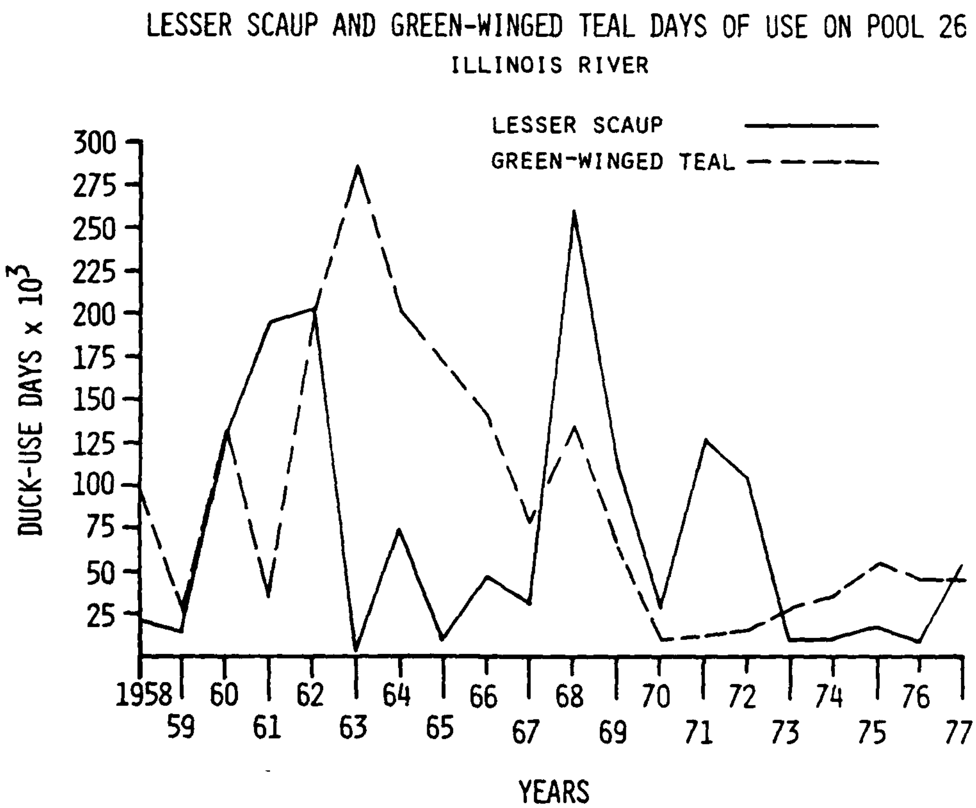
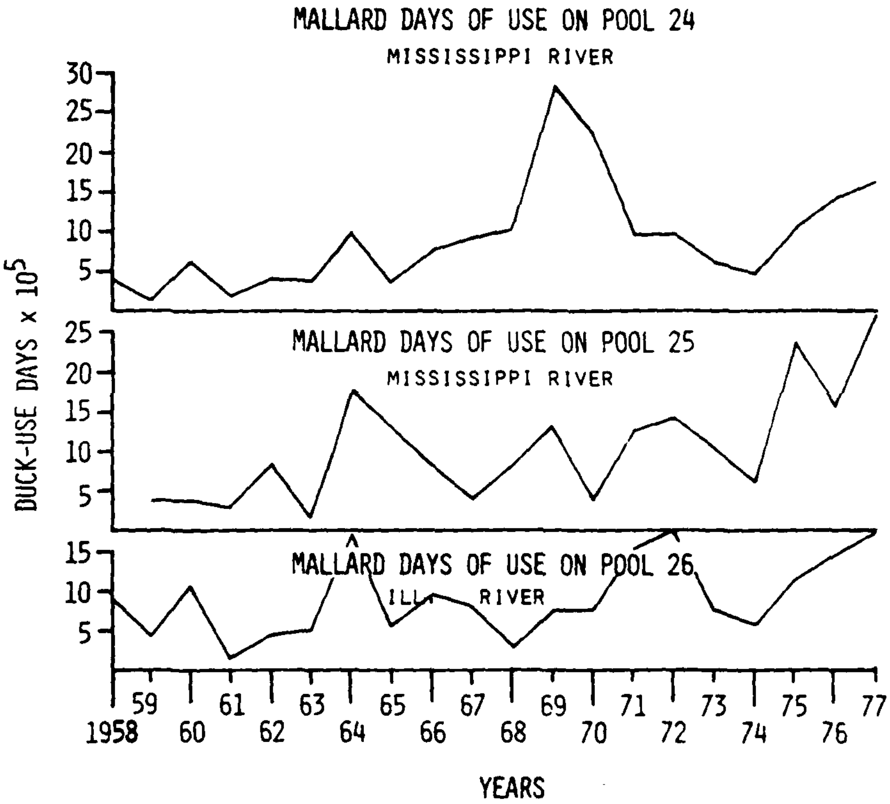


Figure 14.



LESSER SCAUP AND GREEN-WINGED TEAL DAYS OF USE ON POOL 26
ILLINOIS RIVER
LESSER SCAUP
GREEN-WINGED TEAL
DUCK-USE DAYS x 10^3
300
275
250
225
200
175
150
125
100
75
50
25
1958
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
YEARS

Figure 15.


MALLARD DAYS OF USE ON POOL 24
MISSISSIPPI RIVER
30
25
20
15
10
5
DUCK-USE DAYS x 10^5
25
MALLARD DAYS OF USE ON POOL 25
MISSISSIPPI RIVER
20
15
10
5
15
MALLARD DAYS OF USE ON POOL 26
RIVER
10
5
1958
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
YEARS

as a result of the nine-foot channel project increased backwater areas and hence waterfowl brood habitat. Backwater areas initially expanded submerged aquatic and marsh acreage which form excellent brood habitat. Increased sedimentation and turbidity have decreased the value of brood habitat in the backwater areas by reducing the submerged aquatic and marsh vegetation. Increased effectiveness of management practices has helped keep this duck plentiful even though its habitat has been degraded.

Canada, blue, and snow geese use-days have increased in recent years. The Illinois River portion of Pool 26 is utilized to a greater extent than the Mississippi River sections. The reason for this increase is twofold: (1) a large increase in the continental population of Canada geese (Bellrose, 1976: 142), and (2) increased management practices in the study area by state, U.S. Fish and Wildlife Service, and private duck clubs.

In conclusion, the nine-foot navigation project initially benefited waterfowl populations. Increased backwaters provided shallow areas which supported both marsh and submerged aquatic plant growth. These areas provide additional feeding, breeding, and loafing areas for waterfowl. However, as a result of water fluctuations in Pools 25 and 26, waterfowl feeding areas were degraded during several years. The nine-foot channel project has also been a factor which has led to increased sedimentation and turbidity in the Illinois and Mississippi valleys. Increased sedimentation has also occurred as a result of increased erosion from agricultural lands in the watershed.

Increased sedimentation and turbidity have led to the eventual loss of submerged aquatic plants in most of the project area. This loss of plants has been responsible for declining numbers of wigeon, green-wing teal, and lesser scaup in the project area. In addition increased sedimentation has filled shallow areas created by the project which once supported marsh plants, destroying habitat. On the other hand sedimentation has also created more mud flats which produce moist-soil plants if the proper water level manipulation occurs.

Bald Eagle

Pools 24, 25, and 26 form one of the more important wintering grounds for the bald eagle in the United States. Eagles funnel into the upper Mississippi River from extensive breeding grounds embracing Michigan, Wisconsin, Minnesota, Ontario, Manitoba, and the Northwest Territories.

As ice covers the navigation pools in the upper reaches of the Mississippi River, increasing numbers of eagles move downstream to the lower pools. Because of the variability in seasonal ice cover in the navigation pools of the upper river, the numbers found in the project area fluctuate greatly during the fall and winter (Tables 42, 43, 44, & 45).

Pools 24, 25, and 26 are the southern terminus for the large concentration of bald eagles wintering on the Mississippi River. When these pools freeze completely over, the eagles are forced to disperse to less satisfactory feeding grounds.

The nine-foot channel project has had both a beneficial and a detrimental effect upon wintering eagles. With the navigation dams, the tailwaters remain unfrozen for longer periods of time than previously. It is there that the eagles concentrate to catch fish during severe weather in midwinter. However, the lower parts of the pools freeze over earlier than prior to the project, because of the reduction in channel velocity, thereby restricting the eagles' feeding area early in the winter.

Overall, the advantages the eagles gain in obtaining fish from the open tailwaters in midwinter probably outweigh the early winter loss of more extensive feeding grounds caused by the navigation project.

Herons and Their Allies

The family Ardeidae is represented in Pools 24, 25, and 26 by the great blue heron, common egret, black-crowned night heron, green heron, cattle egret, American bittern, and least bittern. These are wading birds that feed on fish, frogs, crayfish, and other invertebrates. All, except the green heron and bitterns, breed in colonies which sometimes number 100 and more nests.

Table 42

Bald Eagle Census Data for the Mississippi River, Pool 24

Date	77-78	76-77	75-76	74 75	73-74	72-73	71-72	70-71	69-70	68-69	67-68	66-67	65-66	64-65	63-64	62-63	61-62	60-61
11/11																		
11/15		5																
11/17	7																	
11/22	7	4																
11/27						2												
11/29		8																
12/1			18			6												
12/2	19																	
12/3					2													
12/5														1				
12/7		17																
12/8			13															
12/9				6														
12/10					14													
12/12	23																	
12/13		14																
12/14																	21	
12/15																		
12/16			18	15														
1/3[a]	24	15																
1/4																		
1/5			26						9									
1/6								8						33				
1/7				19	56		6											
1/8						55										1		
1/9																		7
1/11																	66	
Peak No.	24	17	26	19	56	55	6	8	9	0	0	0	0	33	0	1	66	7

[a] January of the same winter; e.g., if November and December of 1977, January is 1978.

Table 43

Bald Eagle Census Data for the Mississippi River, Pool 25

Date	77-78	76-77	75-76	74-75	73-74	72-73	71-72	70-71	69-70	68-69	67-68	66-67	65-66	64-65	63-64	62-63	61-62	60-61
11/11																		
11/15		2																
11/17	5																	
11/22	10	14																
11/27																		
11/29		11																
12/1			11			28												2
12/2	27																	
12/3					1													
12/5														8				
12/7		22																
12/8			23															
12/9				9														
12/10					21													
12/12	15																	
12/13		20																
12/14																	11	
12/15														3				
12/16			31	10														
1/3[a]	17	40																
1/4															23			
1/5			68						31									
1/6								19						21				
1/7				29	48		4			4								
1/8						72					12					20		
1/9																		14
1/11																	10	
Peak No.	27	40	68	29	48	72	4	19	31	4	12	0	0	21	23	20	11	14

[a] January of the same winter; e.g., if November and December of 1977, January is 1978.

Table 44

Bald Eagle Census Data for the Mississippi River, Pool 26

Date	77-78	76-77	75-76	74-75	73-74	72-73	71-72	70-71	69-70	68-69	67-68	66-67	65-66	64-65	63-64	62-63	61-62	60-61
11/11																		
11/15																		
11/17																		
11/22	8	9																
11/27																		
11/29		6																
12/1			7			2												1
12/2	5																	
12/3																		
12/5																		
12/7		7																
12/8			16															
12/9				4														
12/10					2													
12/12	5																	
12/13		3															1	
12/14																		
12/15																		
12/16			8	6														
1/3[a]	11	23																
1/4															1			
1/5			45						3									
1/6								1						6				
1/7				14	14		4			6								
1/8						6	3				1					27		
1/9																		7
1/11																	30	
Peak No.	11	23	45	14	14	6	4	1	3	6	1	0	0	6	1	27	30	7

[a]January of the same winter; e.g., if November and December of 1977, January is 1978.

Table 45

Bald Eagle Census Data for the Lower Illinois River, Pool 26

Date	77-78	76-77	75-76	74-75	73-74	72-73	71-72	70-71	69-70	68-69	67-68	66-67	65-66	64-65	63-64	62-63	61-62	60-61	59-60
11/11	2																		
11/15		3																	
11/17	4																		
11/22	9	5																	
11/27																			
11/29		18																	
12/1			10			21												4	
12/2	14																		
12/3					4														
12/5																			
12/7		24																	
12/8			37																
12/9				14															
12/10					16														
12/12	18																		
12/13		26																	
12/14																	10		
12/15														52					
12/16			20	11															
1/3[a]	38	28																	
1/4															16				9
1/5			36						36										
1/6								16						7					
1/7				45	5		3												
1/8						23					19					21			
1/9																		26	
1/11																	9		
Peak No.	38	28	37	45	16	21	3	16	36	0	19	0	0	52	16	21	10	26	9

[a]January of the same winter; e.g., if November and December of 1977, January is 1978.

Table 46 shows the location and the number of great blue heron and common egret nests in colonies within the project area. Colonies were most numerous and nests were most abundant in 1962. Thereafter, there was a general decline through the 1960's and 1970's; cursory observation indicates that the number of nesting common egrets and great blue herons greatly decreased during the first half of the 1970's.

Graber (1976: 2) also documented a similar decline in the number of breeding herons and egrets on the Mississippi River between St. Louis and Cairo. He attributed the decline there to two factors: (1) disturbance of nesting colonies by logging and "development", and (2) deterioration in their food-gathering ability stemming from increases in turbidity and sedimentation.

In our judgment the nine-foot waterway initially produced an increase in breeding egrets and herons by enhancing their feeding grounds. Their food supply and feeding areas were increased by the expansion in water surface area, particularly in the lower one-third of each navigation pool.

The clearing of bottomland forests in the impoundment area resulted in losses in potential nest sites, but it would seem that sufficient bottomland hardwoods remain to provide adequate nest sites. The increased turbidity and sedimentation of backwater areas in recent years appears to be an important factor in the recent catastrophic decline in the abundance of herons and egrets.

Cormorants

The double-crested cormorant was a common migratory visitor and bred to a limited extent in the Mississippi valley. The cormorant was listed as occurring in occasional flocks in August 1888 near Quincy, Illinois (Garman, 1896: 131). Smith (1911: 17) recorded several cormorants nesting on Clear Lake near Havana, Illinois. Praeger (1925: 570) reported that in 1890 the double-crested cormorant was abundant in April and October near Keokuk, Iowa on the Mississippi River. Mills, Starrett, and Bellrose (1966: 21) stated that as many as 15,000 cormorants were in the lower Illinois valley on October 16, 1950.

Table -6

Location and Size of Common Egret and Great Blue Heron Nesting Colonies in Pools 24, 25, and 26

Location	1958		1962		1964		1967		1975		1976	
	CE[a]	GBH[b]	CE	GBH	CE	GBH	CE	GBH	CE	GBH	CE	GBH
Lake Meredosia		90		500		150		115		0		0
Nutwood									0	30	0	10
Grafton		45		150		72		70		?	?	?
Gilead (5 miles north)		55	100	100	50	25	200	160		?	?	?
Clarksville	250	110	180	120	115	30	35	80		?	?	?
Golden Eagle					0	24				?	?	?
Blackburn Island (north of Louisiana, Missouri)							100	110		?	?	?
Total	250	300	280	870	165	301	335	535	0	30	0	10

[a]CE = Common Egret.

[b]GBH = Great Blue Heron.

A rapid decline in cormorant numbers has occurred since 1950. By 1965 only 22 cormorants were observed on an aerial inventory of water birds in the Illinois River valley. Between 1965 and 1972 cormorants were only observed once during the fall waterfowl census flight of the Illinois and Mississippi River valleys made by the Illinois Natural History Survey. In recent years a gradual increase in cormorant numbers has occurred in Pools 24, 25, and 26 of the Mississippi River (Table 47).

The cause for the dramatic decline in cormorant numbers is not known at this time. However, the implementation of the nine-foot channel appears to have had little effect on the cormorant.

Shorebirds and Related Species

At times large numbers of shorebirds, gulls, and terns, members of the order Charadriiformes, occur within Pools 24-26. Shorebirds are most abundant from mid-summer through early fall when mud flats are exposed by receding water. This condition is prevalent only in those summers that river flows are minimal.

Three areas within the project area are noted for shorebird concentrations: (1) Lake Meredosia on the Illinois River at the upper end of Pool 26, (2) Calhoun Refuge, a short distance above the mouth of the Illinois River, and (3) Batchtown area, at the lower end of Pool 25.

A list of the occurrence of shorebirds and gulls on the three areas is shown in Table 48. The most abundant sandpipers are the following: pectoral, least, semipalmated, and lesser yellowlegs. Other important shorebirds are killdeer, woodcock, and common snipe.

Gulls are many times more abundant than terns, which occur late in the spring and early in the fall. On the other hand, gulls are most numerous from mid-fall through mid-spring. During this period many thousands occur within the project area. Ring-billed gulls composed the bulk of the birds, followed by herring gulls.

Increased sedimentation has resulted in the filling of marshy areas creating shallows which are exposed during the low water in summer and fall.

Table 47

Cormorant Census Data for Pools 24, 25, and 26, Illinois and Mississippi Rivers, 1968-1977[a]

1977	9/20	9/27	10/4	10/6	10/7	10/11	10/13	10/14	10/20	10/23	11/11	11/12	11/17	11/19	Total
I26[b]	29	11	23			21									84
M26		18	5												23
M25						7									7
M24						14									14
1975															
I26				13			16		32		15		19		95
M26													20		20
M25							6		13				12		31
M24															0
1974															
I26					9							83		30	122
M26															0
M25															0
M24												14			14
1972															
I26															0
M26															0
M25										47					47
M24															0
1968															
I26															0
M26															0
M25								12							12
M24															0

[a]No cormorants observed, 1969-1971, 1973, 1976. [b]I26 = Pool 26, Illinois River; M26 = Pool 26, Mississippi River, etc.

Table 48

Shorebirds and Related Species

	Meredosia	Calhoun	Batchtown
American Avocet		x[a]	
American Golden Plover		x	
Black-Bellied Plover	x		
Semipalmated Plover	x	x	
Killdeer	*[b]	*	*
Buff-Breasted Sandpiper	x		
Solitary Sandpiper	x		
Spotted Sandpiper	x	x	x
Willet		x	
Greater Yellowlegs	*	x	x
Lesser Yellowlegs	*	x	x
Stilt Sandpiper	*	x	x
Short-Billed Dowitcher	x	x	
Long-Billed Dowitcher		x	x
Pectoral Sandpiper	*	*	x
Dunlin		x	x
Sanderling	x		
Least Sandpiper	*	x	
Semipalmated Sandpiper	*	x	x
Western Sandpiper		x	
Wilson's Phalarope	x	x	x
American Woodcock	x	*	*
Common Snipe	x	*	*
Herring Gull	*	*	*
Ring-Billed Gull	x	*	*
Franklin's Gull		x	
Common Tern		x	x
Forster's Tern		x	x
Caspian Tern		x	x
Black Tern	*	x	x

[a]x = present.

[b]* = 1,000 or more use days.

In the years that pool levels recede from mid-summer on, the navigation project is beneficial to shorebirds. Under these conditions, more mud flats are available than during the pre-project years.

Gulls and terns also benefited from the nine-foot channel project. More surface water was created, increasing their food source, minnows and other fishes.

Other Game Species

Several other game species are found in the study area. The bob-white quail, ringneck pheasant, mourning dove and wild turkey are the four major game birds found in the study area. These species dwell in open forests, hedgerows, and cropland (Robbins et al., 1966: 82, 90, 154). Inundation or logging of bottomlands in conjunction with the nine-foot channel had a minimal effect on these habitats and subsequently these birds.

The American woodcock and common snipe are found in moist woodlands and along marshes and river banks (Robbins et al., 1966: 126). The moist bottomlands of Pools 24, 25, and 26 supply feeding habitat for migrating woodcock and snipe. A small number of breeding woodcock in Illinois and Missouri also exploit this habitat. Inundation of bottomland as a result of the nine-foot channel probably destroyed feeding sites used by the woodcock and snipe.

The common gallinule, sora, and Virginia rail breed on and migrate through the study area (Sanderson, 1977: 112, 60, 49). These birds breed and feed in marsh areas (Sanderson, 1976: 110, 58, 46). The nine-foot channel initially created additional marsh areas, providing more habitat for these birds. Increased sedimentation, attributed primarily to agricultural pollution coupled with the dams' slowing the current and deepening the water, has filled marsh areas, reducing the initial benefit to these species.

Other Avifauna

Song birds (Passeriformes) are the most abundant of all birds. Hundreds of thousands of individuals embracing over 100 species migrate through the project area. About 50 species remain to breed. Quantitative

data on these birds are not available, but general conclusions can be drawn.

Most of the passerine species that frequent the project area are associated with the bottomland forest. Extensive clearing of the bottomland forest in preparation for pool impoundment was destructive of habitats used by song birds both in migration and for breeding. Breeding song birds most affected were: great crested flycatcher, wood pewee, tree swallow, black-capped chickadee, tufted timouse, white-breasted nuthatch, house wren, Bewick's wren, Carolina wren, wood thrush, red-eyed vireo, warbling vireo, prothonotary warbler, yellow-throat, and American redstart.

Other birds, closely allied to Passeriformes, that were adversely affect by clearing bottomland timber are the following woodpeckers: pileated, hairy, downy, red-bellied, and red-headed.

The only area that wasn't cleared was Calhoun Point in Pool 26. A cooperative agreement between the Army Corps of Engineers, Illinois Natural History Survey, and National Park Service allowed this area to be flooded. Inundation killed mature timber, temporarily creating additional habitat for woodpeckers and cavity-nesting birds. The major species of birds that were affected are the red-bellied, red-headed, downy, hairy, and pileated woodpeckers; the yellow-shafted flicker; tree swallow; and prothonotary warbler (Yeager, 1949: 62). For the song birds and woodpeckers there was no mitigation for the extensive bottomland forests that were cleared.

Muskrats

The implementation of the nine-foot channel benefited muskrat populations on Pools 24, 25, and 26 of the Illinois and Mississippi Rivers. Muskrats depend on marsh vegetation for both feeding and house construction. The implementation of Pools 26 and 25 in 1938 created 600 acres of shallow water at Calhoun Point, Illinois and approximately 1,000 acres at Batchtown, Illinois. Much of this acreage supported marsh vegetation creating habitat for muskrats. The importance of these water areas is reflected by partial counts of

of trappers' catches for Calhoun Point taken from Yeager and Rennels (1943: 49). Harvested muskrats numbered 50 to 75 during the 1938-39 trapping season and jumped to 225 during the 1939-40 season. Other marsh habitat created by the nine-foot channel would have had similar beneficial effects on muskrat populations.

Increased sedimentation caused by intensified agricultural tillage, coupled with decreased water velocity and increased water levels as a result of the navigation dams, have filled in shallow marsh areas. The plants that occupied these areas, mainly river bulrush and smartweeds, are used by muskrats to build houses (Brown and Yeager, 1943: 456). As a result of sedimentation, many of the marsh plants which were responsible for the increase of muskrat populations had been replaced by moist soil species. Narrative reports for the Mark Twain National Wildlife Refuge (Calhoun and Batchtown units) indicate that by 1960 muskrats had gradually changed from building houses to using bank dens. The initial benefit derived from the nine-foot channel project has retrogressed as a result of sedimentation.

Information obtained from narrative reports also indicates that extreme fluctuations as a result of manipulation of pool levels have a detrimental effect on muskrat populations. Keenlyne (1974: 20), Bellrose (1943: 175), and Steele (1946: 20) have found that extreme fluctuations adversely affect muskrat populations in the upper Mississippi and Illinois Rivers. Steele (1946: 20) indicated a drawdown of six or more inches following a freeze-up after muskrats had established winter quarters and gathered emergency food supplies would force many of the animals to abandon their lodges during mid-winter due to inaccessibility of food in the vicinity of their lodge. The dams could be beneficial for muskrats by stabilizing water levels. However, drawdowns, especially in Pool 25 in 1951, 1954, 1955, and 1961, have been deleterious to muskrats.

Muskrat populations at the Calhoun and Batchtown units of Mark Twain National Wildlife Refuge increased initially but declined in the middle 1940's as a result of pool level manipulation. The population then began to increase in the 1950's until the middle 1960's except

during periods of extreme water fluctuations. They remained stable until the severe floods of 1969 and 1970 reduced their numbers. Muskrat populations made a minor recovery following the floods and have remained stable. The nine-foot channel project initially benefited muskrats; however, due to sedimentation and subsequent destruction of aquatic and marsh plants, much of the early benefits have been lost.

Beaver

The beaver was once common along rivers and streams in both Illinois and Missouri until the 1800's. Their numbers gradually decreased as a result of overtrapping and destruction of habitat. Only a few colonies remained in Missouri in 1895 (Schwartz, 1959: 165). By the late 1800's or early 1900's beaver were exterminated in Illinois (Hoffmeister and Mohr, 1972: 156). The Illinois Department of Conservation reintroduced beavers in Jersey County (Illinois River Pool 26) in 1936. Several other reintroductions were made in southern Illinois from 1935-1938 (Mohr, 1943: 533). The repopulation of the Missouri River and its tributaries in north Missouri was the result of colonization by either remnants of the original population or migrants from farther upstream (Schwartz, 1959: 165). As a result of these reintroductions and movements from adjacent areas, the beaver is now a common mammal of Pools 24, 25, and 26 on the Illinois and Mississippi Rivers.

Perusal of narrative reports written by management personnel of the Mark Twain Natioanl Refuge system, Calhoun and Batchtown units (Pools 26 and 25) indicate that beaver populations have steadily increased from 1949 until the mid-1960's. The populations have remained static from the mid-1960's to the present time.

Two possible factors responsible for the increase in beaver populations would be low pelt prices and increased sedimentation (Table 49). Since the repopulation of beaver in the Illinois and Mississippi River valleys, the price of beaver pelts has been low. This has resulted in little trapping pressure, allowing the beaver population to grow. Increased sedimentation, which has been a result of agricultural erosion and implementation of the nine-foot channel, may have been beneficial

Table 49

Fur Harvest and Average Pelt Prices for the State of Missouri and the Northeast Portion of Missouri

	Raccoon Fur Harvest			Muskrat Fur Harvest		
	Missouri	N.E.Mo.	Ave. Price	Missouri	N.E.Mo.	Ave. Price
1934-35	15,644		$ 1.80	67,058		$ 0.80
1940-41	11,000		2.15	120,000		1.30
1941	13,517		3.00	85,464		1.15
1942	14,547		3.10	104,872		1.70
1943	27,598		4.40	182,846		1.90
1944	38,106		2.16	173,347		1.80
1945	53,347	13,810	2.50	212,269	41,389	2.00
1946	77,564	20,504	1.50	217,847	42,113	1.50
1947	71,804	17,932	1.00	118,670	15,274	2.30
1948	79,793	20,697	1.00	76,034	9,237	1.75
1949	83,007	19,787	0.90	115,861	13,224	1.25
1950	94,854	23,609	1.80	139,197	11,673	1.85
1951	100,586	25,368	1.70	111,542	12,177	1.55
1952	120,803	31,251	1.00	120,435	15,264	1.10
1953	108,641	28,127	1.00	63,455	8,812	0.90
1954	104,828	30,829	1.00	43,116	6,053	1.00
1955	121,906	34,464	1.40	38,036	4,897	1.20
1956	122,991	29,442	1.05	67,139	11,495	0.92
1957	112,284	28,432	0.85	46,805	7,986	0.70
1958	77,963	19,691	0.65	53,182	7,592	0.60
1959	135,870	35,481	1.50	119,766	18,111	0.75
1960	141,106	34,076	1.45	86,282	12,252	0.65
1961	137,779	31,582	1.60	65,431	11,589	0.67
1962	201,308	46,911	1.95	119,754	25,815	0.90
1963	132,242	29,182	1.15	101,883	24,078	1.15
1964	138,720	33,033	1.00	90,311	26,500	1.02
1965	155,147	37,811	1.70	128,256	40,064	1.40
1966	140,836	33,873	1.60	130,026	36,619	0.91
1967	108,604	24,831	1.75	63,657	15,411	0.75
1968	152,547	34,162	3.87	64,209	14,013	0.91
1969	203,665	44,976	2.55	105,425	25,691	1.10
1970	120,796	28,015	1.12	71,911	19,998	0.92
1971	173,335	39,755	2.60	92,993	23,154	1.30
1972	194,429	43,760	6.65	69,012	16,289	2.05
1973	234,233	48,279	7.45	58,341	12,436	2.15
1974	255,910	58,738	7.35	94,009	27,891	2.40
1975	276,524	59,670	13.90	89,727	22,289	3.00
1976	247,671	52,810	17.10	82,708	17,423	4.10

Sheet 1 of 2

Table 49 (concluded)

	Beaver Fur Harvest			Mink Fur Harvest		
	Missouri	N.E.Mo.	Ave. Price	Missouri	N.E.Mo.	Ave. Price
1934-35				11,598		$ 2.10
1940-41				13,626		5.60
1941				7,888		6.80
1942				6,637		5.60
1943				10,436		10.00
1944				11,156		10.50
1945	25[a]		27.06	14,144	3,428	25.50
1946	27[a]	8	18.00	22,658	6,041	14.00
1947	43[a]		18.70	19,104	4,388	26.00
1948	32[a]		16.29	closed season		14.00
1949	166[a]	11	10.43	16,110	2,783	15.00
1950	247[a]	20	10.00	19,946	2,968	22.00
1951	197[a]	8	9.92	15,987	1,923	16.00
1952	485[a]	106	6.06	21,359	2,151	15.00
1953	1,893	336	5.00	15,552	1,505	14.00
1954	2,333	447	5.25	11,060	1,243	18.00
1955	3,132	580	5.80	8,120	779	17.00
1956	3,927	829	3.00	8,682	974	14.00
1957	2,177	492	3.50	7,052	720	10.50
1958	1,950	510	3.60	8,210	605	12.00
1959	3,864	952	3.95	14,829	1,409	14.00
1960	5,091	1,084	4.30	10,014	769	10.30
1961	3,268	889	5.00	7,655	605	8.50
1962	6,437	1,959	4.70	11,929	1,154	10.60
1963	6,068	1,655	5.60	10,126	922	10.30
1964	4,187	1,109	5.13	7,773	809	7.90
1965	4,190	1,330	5.33	7,126	877	7.00
1966	5,607	1,607	6.40	7,029	845	6.30
1967	2,989	675	7.85	3,749	411	6.00
1968	2,567	359	8.15	5,122	453	8.42
1969	3,771	504	7.00	6,949	628	6.15
1970	2,257	197	4.65	4,202	440	3.95
1971	2,938	303	5.35	5,433	741	5.30
1972	3,275	455	9.35	5,437	676	11.10
1973	2,098	182	8.20	5,198	380	11.05
1974	3,246	526	5.75	6,622	619	6.45
1975	2,320	349	4.80	5,863	641	7.70
1976	5,888	721	8.30	6,875	505	14.10

[a]Damage permits only.

Sheet 2 of 2

to the beaver. Mud flats created through sedimentation have been pioneered by black willow, cottonwood, and silver maple trees, which are preferred foods of the beaver.

Probably the 9-foot channel project had little effect on potential beaver habitat. It was both destructive and beneficial, depending upon the amount of flooding: too much was destructive of beaver habitat, moderate inundation was beneficial.

Raccoon

Raccoons are present throughout Illinois and Missouri with the highest densities found in extensively wooded bottomland areas. Bottomland forests of the Illinois and Mississippi River valleys provide excellent habitat for the raccoon with number reaching 100 animals per square mile under favorable conditions (personal communication, Glen Sanderson, wildlife biologist, Illinois Natural History Survey). Maturity of bottomland forest and a plentiful water supply improve the quality of habitat.

Trapping studies have indicated that raccoon populations decreased in Illinois during the 1930's (Brown and Yeager, 1943: 463). During 1938-39, Brown and Yeager reported a density of 5 raccoons per square mile in Calhoun County. This was the heaviest raccoon population encountered during their fur resource study of Illinois, which indicates the importance of the Illinois and Mississippi River bottomland forest. Beginning in the 1940's the raccoon population began to increase, and it is now abundant in both the Illinois and Mississippi valleys.

Furbearer harvest studies were obtained from Dave Erickson, small game biologist for the Missouri Department of Conservation. Tables 50-53 illustrates the increased fur harvest of raccoons in the counties of Missouri bordering Pools 24, 25, and 26 on the Mississippi, which is indicative of the increase in raccoon population bordering the Mississippi. Fur harvest figures from the Missouri DOC indicate than the northeast portion of the state consistently harvests more raccoons. The rising market value of pelts the last few years has resulted in the large increase of raccoons harvested in 1975 and 1976 (Table 49).

Table 50

Missouri Fur Harvest for Counties in the Study Area, 1951-1977: Ralls County

	Trapping Permits	Opossum	Striped Skunk	Muskrat	Spotted Skunk	Raccoon	Mink	Weasel	Red Fox	Grey Fox	Coyote	Bobcat	Beaver	Badger
1951-52		254	14	264	1	1,006	55	1	24	4				
1953-54		72	7	244	13	1,056	55		10	4			1	
1955-56	13	77	4	87	5	1,126	21		9	2			1	
1957-58	17	38	10	64	1	623	3		1	1			2	
1958-59	18	5		15		501	4							
1961-62	21	77	9	1,160	3	1,259	36		28	1	1		73	
1963-64	19	59	1	1,254	2	600	13		8	6			85	
1964-65	20	35		2,147	1	920	19		1				116	
1967-68	29	74		412	6	1,126	13		13	4			28	
1969-70	31	193	3	679	2	1,514	10		43	8	11		4	1
1971-72	20	151	8	742	1	1,526	7		13	6	11		1	1
1972-73	26	163	15	377		1,070	13	1	21	8	76		5	2
1975-76	31	303	4	294		1,516	4		19	11	112		1	
1976-77	33	312	14	547	1	1,234	4	3	16	19	170		12	3

Table 51

Missouri Fur Harvest for Counties in the Study Area, 1951-1977: Pike County

	Trapping Permits	Opossum	Striped Skunk	Muskrat	Spotted Skunk	Raccoon	Mink	Weasel	Red Fox	Grey Fox	Coyote	Bobcat	Beaver	Badger
1951-52		423	51	608	2	1,711	80	2	28	9				
1953-54		341	39	627	4	3,485	59	1	15	7			1	
1955-56	31	157	37	196	2	3,102	22		11	8	1		11	
1957-58	36	166	20	872	3	2,684	29		14	7			38	
1958-59	17	37	19	482	4	1,920	33		2	1	1		-[a]	
1961-62	34	381	27	1,341	2	3,404	46		3	2			78	
1963-64	56	308	9	1,632	7	2,195	41		1	1			102	
1964-65	53	292	15	3,760	8	2,494	41		4	3			30	
1967-68	73	315	9	1,294	3	2,012	50		9	8			25	
1969-70	70	388	4	1,947	1	3,081	34		19	15	5		6	
1971-72	56	233	7	1,387		2,647	73		1	8	22	1	13	
1972-73	76	240	22	679		2,258	45		9	11	29		16	2
1975-76	73	561	6	995		2,559	19		17	13	195		6	
1976-77	100	570	19	1,412		2,014	24	4	37	18	236	2	20	1

[a]No record.

Missouri Fur Harvest for Counties in the Study Area, 1951-1977: Lincoln County

	Trapping Permits	Opossum	Striped Skunk	Muskrat	Spotted Skunk	Raccoon	Mink	Weasel	Red Fox	Grey Fox	Coyote	Bobcat	Beaver	Badger
1951-52		622	21	958	7	1,310	119	4	12	9				
1953-54		403	36	850	6	1,642	132		8	16			10	
1955-56	45	240	67	273	6	2,253	46		39	1			21	
1957-58	41	110	15	525		2,401	88	1	13				9	
1958-59	39	101	15	573		2,002	54		20				-[a]	
1961-62	41	455	12	1,331	1	2,526	57		6	3		1	83	
1963-64	63	234	9	2,028	4	2,348	88		1	1			51	
1964-65	55	234	2	2,336	6	2,315	93			1			77	
1967-68	56	85	3	790		1,256	35		2	1			49	
1969-70	73	352	9	1,871	2	2,069	95	1	23	20	3		23	
1971-72	66	329	3	2,524	1	3,379	106	4	13	5	13		28	
1972-73	78	278	6	1,423		2,468	81		20	17	55		10	
1975-76	114	766	7	1,729		3,772	67	3	31	31	86	3	13	
1976-77	110	666	5	1,420		3,139	47		36	24	159		18	

[a]No record.

Table 53

Missouri Fur Harvest for Counties in the Study Area, 1951-1977: St. Charles County

	Trapping Permits	Opossum	Striped Skunk	Muskrat	Spotted Skunk	Raccoon	Mink	Weasel	Red Fox	Grey Fox	Coyote	Bobcat	Beaver	Badger
1951-52		765	53	1,225		1,076	148	5	51	25	1		3	
1953-54		339	19	881		1,272	157		19	5	3		13	
1955-56	72	175	19	497	2	1,239	117	12	17	4			44	
1957-58	84	253	23	1,638	2	1,955	148	1	16	4			38	
1958-59	67	67	11	799	2	1,277	127	2	7				-[a]	
1961-62	79	215	13	1,568	4	1,352	72	2	17	2	2		51	
1963-64	109	191	26	3,100	13	1,363	128		15	10			59	
1964-65	94	192	19	3,834	14	1,742	127		7	1			77	
1967-68	93	146	10	2,077	5	1,207	49	2	13	7	2		65	
1969-70	102	378	21	7,041	6	2,579	116		75	31	16		39	
1971-72	99	261	7	3,942		2,111	117		35	17	11	1	43	
1972-73	123	402	20	2,000		2,282	123	1	42	22	33	1	74	
1975-76	187	866	8	5,834		3,235	146		51	46	107	2	32	1
1976-77	216	532	55	2,705	6	1,862	79		32	46	136	6	34	1

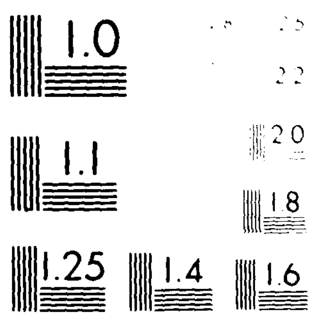
[a]No record.

AD-A115 985 ILLINOIS NATURAL HISTORY SURVEY HAVANA RIVER RESEARCH LAB F/G 6/6
FISH AND WILDLIFE HABITAT CHANGES RESULTING FROM CONSTRUCTION O--ETC(U)
APR 79 R E SPARKS, F C BELLROSE, F L PAVEGLIO

UNCLASSIFIED NL

3 OF 3
AD A
115 985

END
DATE
FILMED
7-82
DTIC


1.0
2.2
2.0
1.1
1.8
1.25
1.4
1.6

The nine-foot channel affected raccoon populations in several ways. An increase in water area initially provided more feeding habitat for raccoons, but in recent years sedimentation reduced the quality and quantity of aquatic food. Slower current velocity and deeper water as a result of the nine-foot channel coupled with increased agricultural runoff have silted in valuable marsh areas which provide feeding areas for raccoons. Extensive bottomland clearing made in conjunction with the implementation of the nine-foot channel along the Illinois and Mississippi Rivers in Calhoun County destroyed habitat, forcing raccoons into the uplands (Brown and Yeager, 1943: 463).

Population data for raccoons found exclusively in the bottomland forest of the Illinois and Mississippi are not available: therefore, a quantitative interpretation of raccoon populations affected by the nine-foot channel is not possible.

Mink

The mink, an animal that is highly adaptable and at home on land or in the water, was reported by Yeager (1949: 60) as being affected by the Calhoun Point inundation on Pool 26 of the Illinois River less than any other fur species.

The abundance of mink is a function of shoreline: the more shoreline, the greater the potential population of this species. The amount of shoreline decreased in the lower third of Pools 24-26 with the submergence of islands; shoreline was enhanced in the middle third of the pools, and remained about the same in the upper third.

Therefore, potential mink habitat both decreased and increased as a result of the 9-foot channel project. Overall the losses and benefits probably balanced. Although no quantitative data on mink inhabiting the bottoms ~~are~~ available, narrative reports for the Calhoun and Batchtown units of the Mark Twain Refuge system indicate that mink populations fluctuated as a result of pool operations during the 1940's and early 1950's. The populations increased steadily until the mid-1960's and then declined. This decline is presumably a result of two factors: (1) a loss of marsh habitat attributed to sedimentation, and (2) trapping pressure (Tables 50-53).

Other Furbearers

Several other furbearers occur in the bottomland forest of Pools 24-26 of the Mississippi and Illinois Rivers. Furbearers that occupied high semi-dry bottoms were adversely affected by inundation. Yeager (1949: 60, 61) indicated that striped skunks, both red and gray foxes, and opossums were evicted from flooded bottoms at Calhoun Point, which is in Pool 26 at the confluence of the Illinois and Mississippi Rivers. No quantitative data are available for furbearers inhabiting the bottoms of Pools 24-26. Fur harvest records for the Missouri counties bordering the project area are given in Tables 50-53. However, these figures include data for areas other than the bottomlands bordering the Mississippi. It is felt that inundation of bottomlands in Pools 24-26 as a result of the nine-foot channel had an adverse effect on furbearers that occupy this habitat.

White-Tailed Deer

As a result of forest clearing and hunting pressure, white-tailed deer had been extirpated from Illinois and Missouri in the early 1900's. By the 1930's as a result of reintroductions and immigration, the deer population began to increase until it had recovered sufficiently to allow sport hunting to reopen in the 1950's in most counties of Illinois and Missouri. The first deer were observed on the Mark Twain National Wildlife Refuge (Calhoun and Batchtown Divisions) in 1950.

The bottomland forest of the lower Illinois and Mississippi Rivers provides some of the best habitat for deer in the western portion of Illinois. The heavily wooded section near Beardstown has one of the largest populations found along the length of the Illinois River. Deer kill figures for counties bordering the Illinois River were obtained from Forrest Loomis, deer biologist for the Illinois Department of Conservation (Table 54). They include deer killed in both upland and bottomland areas. Actual numbers of deer inhabiting bottomland forest are not available, but the comparative distribution of deer populations along the Illinois valley are reflected in the distribution of the kill.

Table 54

Illinois Deer Kill Figures for Counties Bordering Illinois and Mississippi Rivers, Pools 24, 25, and 26

County	1974		1975		1976	
	Harvest	HS[a]	Harvest	HS	Harvest	HS
Schuyler	244	3.6	330	3.5	311	3.4
Cass	116	5.4	82	8.2	103	6.5
Brown	245	4.0	312	3.8	317	3.5
Morgan	72	5.1	115	4.5	82	6.0
Pike	461	3.4	577	3.4	527	3.5
Scott	79	4.6	99	5.2	97	5.0
Calhoun	133	5.3	132	6.7	133	6.4
Greene	101	4.8	118	4.7	120	4.0
Jersey	46	9.9	48	10.8	48	10.0
Madison	28	8.9	44	7.3	41	6.8

[a]HS = Hunter success, number of hunters/number of deer killed.

The removal of vast acreages of bottomland forest in preparation for impounding waters in Pools 24, 25, and 26 resulted in the loss of much potentially important deer range. The greatest single area of loss occurred between Grafton and Hardin in Pool 26.

In Missouri the largest population of deer occurs in the southern portion of the state, but sizeable numbers are found in the bottomlands adjacent to Pools 24, 25, and 26. Deer kill figures for the counties bordering Pools 24, 25, and 26 were obtained from Wayne Porath, deer biologist with the Missouri Department of Conservation (Table 55). Like the figures from Illinois, they include deer killed in both upland and bottomland areas but represent the distribution of deer killed along the Mississippi valley. It was estimated that from 30-40 deer per square mile occupy the bottomland timber of Pools 24, 25, and 26. The continued clearing of bottomland timber throughout Illinois and Missouri as a result of intensified agricultural practices has reduced deer habitat and increased the value of the remaining Illinois and Mississippi River bottomland forest. Further destruction of bottomland timber through clearing or inundation would adversely affect the deer population.

Squirrels

Two species of squirrels occupy the floodplain forest of the Illinois and Mississippi Rivers. The fox squirrel, usually the most numerous, occupies both extensive and small tracts of woods, while the grey squirrel, which is often less abundant, usually occurs only in extensive tracts of mature woodlands. The main food source of both species is mast of hardwood trees and flowers, fruits, and buds of elms and maples. Mature trees also provide hollows for breeding and protection. The nine-foot channel project adversely affected squirrel populations in two ways: (1) logging of mature trees in preparation for inundation, and (2) increased water levels which affected survival of mature trees.

The Illinois River bottomland can support a density of up to two squirrels per acre, depending on the quality of the habitat (personal communication, January 24, 1978, S. Havera, squirrel biologist, Illinois

Table 55

Missouri Deer Kill Figures for Counties Bordering the Mississippi River, Pools 24, 25, and 26

	St. Charles	Lincoln	Pike	Ralls
1954	2[a]	12[a]	20[a]	
1955	7[a]	17[a]	15[a]	
1956	11[a]	11[a]	17[a]	
1957	12[a]	26[a]	29[a]	
1958	42[a]	41[a]	51[a]	
1959	132	181	180	60[a]
1960	178	227	195	47[a]
1961	121	137[a]	201	56[a]
1962	186	141	138	213
1963	182	162	188	49[a]
1964	218	167	186	195
1965	209	106[a]	199	66[a]
1966	217	155	203	248
1967	149[a]	111[a]	207	96[a]
1968	163	119	209	249
1969	257	186	248	140[a]
1970	230	165	263	377
1971	262	186	315	414
1972	330	198	309	362
1973	278	224	406	514
1974	307	184[a]	264[a]	282[a]
1975	444	546	759	782
1976	446	388	599	624

[a]Bucks only season.

Natural History Survey, Urbana, Illinois). Don Christison estimated that the Mississippi River bottoms of Pools 24, 25, and 26 would support one or two squirrels per acre depending on maturity and species composition of the bottomland forest (personal communication, January 16, 1978, Missouri Department of Conservation). A population average of one squirrel per acre is considered a normal fall density. It should be noted that the addition of forest acreage, which was a result of black willows pioneering newly formed mud flats as a result of increased sedimentation, provides little additional habitat. Black willows are of minimal importance to squirrels and provide neither food nor nesting sites.

The nine-foot channel project had an adverse effect on squirrel population by the destruction of habitat through inundation and clearing of bottomland forest. Also, as a result of this loss of timber and the creation of more edge habitat, the species composition changed from proportionally more grey squirrels to proportionally more fox squirrels, as was noted at Calhoun Point (Yeager, 1949: 61).

Rabbits

The cottontail rabbit is ubiquitous throughout Illinois and Missouri. Hoffmeister and Mohr indicate that the rabbit is found along fencerows and margins of wood lots, forest edges, and dry bottomlands (1972: 194). The high, semi-dry bottomlands of the Mississippi valley provided habitat for the cottontail before the implementation of the nine-foot channel. Many of these areas have now been inundated by the nine-foot project and have limited populations of rabbits in the bottomland (Green, 1960: 4). Yeager (1949: 61) indicated that rabbits were notably scarce on Calhoun Point even before inundation, a result of the very low, wet nature of the bottomland.

Quantitative population figures are not available for cottontail rabbits in the Mississippi and Illinois River bottomland. Removal of bottomland timber and subsequent inundation would have had an adverse effect on cottontail rabbit populations in the Illinois and Mississippi River bottoms.

SUMMARY

1. Agricultural practices, such as clearing of fence rows and bottomland timber and increased acreages of row crops with increased erosion, are the major contributors of increased sediment and turbidity to the Illinois and Mississippi Rivers. In addition, municipal sewage effluents, construction activities, and certain industrial discharges add to the sediment loads.

2. The 9-foot channel project has also increased turbidity and contributed sediment to backwater areas. The construction of the navigation dams increased the water levels at the dam sites in Pools 24, 25, and 26 by 9, 10, and 9 feet respectively. The dams also slowed the velocity of the Illinois and Mississippi Rivers, reducing their silt-carrying capacity and resulting in a greater sedimentation rate. Increased barge traffic associated with the 9-foot channel increased turbidity in two ways: (a) movement of the barges and the associated towboat resuspends sediment, and (b) the wake from barges contributes to bank erosion and resuspends sediment in shallow areas. During rising river stages this resuspended sediment can be carried into the backwaters where it settles, eventually destroying fish and aquatic wildlife habitats.

3. Backwater habitat for some species of fish, such as carp, bass, and sunfishes, increased following impoundment of the Mississippi River by navigation dams. Within the study area of Pools 24, 25, and 26, there is a total of approximately 73 square miles of aquatic habitat at normal pool elevations. Although this certainly represents a gain in backwater or slackwater habitat, pre-construction acreage was unavailable for comparison. Physical loss of physical alteration of backwater habitat as a result of sedimentation has been, and continues to be a problem.

4. No specific information was available on the effects of Dams 24, 25, and 26 on fish migration.

5. In the period 1903 to 1944, several fishes which prefer a clear-water environment with sand or gravel bottoms and appreciable current declined or disappeared from the upper Mississippi River: the Ozark minnow, blackfin shiner, redfin shiner, steelcolor shiner, Southern redbelly dace, freckled madtom, and crystal darter. In addition to these forage fishes, three commercial fishes (pallid sturgeon, river redhorse, and brown bullhead) and a predatory fish (alligator gar) virtually disappeared from the upper Mississippi. The pallid sturgeon was considered rare in the upper Mississippi River in the period 1876-1903, and was thought to prefer a swift-water habitat. The river redhorse is intolerant of turbidity and siltation, and the brown bullhead is also considered sensitive to turbid waters. These changes in the fish fauna of the upper Mississippi River are probably related to reductions in current velocity caused by the navigation dams and to increased sedimentation and turbidity brought about by both navigation dams and increased sediment input from tributaries.

6. Winter drawdowns in Pools 24, 25, and 26 in the 1940's often resulted in large fish kills. Winter drawdown has not been practiced by the St. Louis District since 1970.

7. There is very little information on the actual impact on fishes of maintenance dredging of the channel, disposal of dredged material, and the construction and maintenance of regulatory works such as dikes and bank revetments. Dredging and deposition of dredge spoil may affect fish food organisms. Fish are known to congregate in the tailwaters below the dams, and fishermen likewise congregate there. The fish probably gather below the dams for several reasons: (a) the water is swift and well-oxygenated below the dams, (b) the dams may impede the normal upstream movements of certain fishes, and (c) there is an abundance of food organisms, such as insects, which are continually swept off the dams and locks. In a similar fashion, wing dikes and riprap may offer good habitat and a source of insect food for certain species of fish.

8. Fish surveys conducted in 1934, 1942, and 1967 with hoop nets show that the number of game fish caught in the Alton Pool of the Illinois River declined by at least 78 percent between 1934 and 1942, and declined further from 1942 to 1967. The catch of non-game fish increased by 50 to 74 percent between 1934 and 1942, primarily as a result of increases in gizzard shad, carpsuckers, and carp.

9. Two major changes which may have affected fish populations in the study reach of the Illinois River in the period 1934-1942 were: (1) Lock and Dam 26 at Alton was put into operation 1 May, 1938, and (2) diversion of water from Lake Michigan into the upper reach of the Illinois Waterway at Chicago was reduced from 6,500 cubic feet per second (cfs) to 5,000 cfs starting 31 December 1935 and further reduced from 5,000 to 1,500 cfs starting 31 December 1938. Domestic pumpage was allowed, in addition to these amounts of diversion.

10. In a 1942 survey of fish populations in the Alton Pool of the Illinois River, more game fish were taken in Meredosia Lake (66.35 game fish per net-day) than in side channels or the main channel of the river (greatest catch: 26.02 game fish per net-day in the channel at Kampsville). Meredosia Lake has since been degraded by an accumulation of oxygen-demanding sediment, which probably plays a role in occasional fish kills observed in the summer.

11. The commercial harvest of fish from the study reach of the Illinois River has been relatively constant since 1950, in contrast to upstream reaches where the harvest has shown a steady decline since 1950. Starting in 1962, the Alton Pool of the Illinois River consistently has ranked second in production among four pools in the Illinois River with commercial fisheries. Some commercial fishermen report that they do not fish the main channel borders of the Illinois River, because the currents and wave wash associated with the passage of barges collapse their nets.

12. In 1963, the condition factor of carp, a commercial species, was substantially better in the study reach than in upstream pools, probably because more food items, such as fingernail clams, were available on the bottom in the study reach. Fingernail clams and snails had been eliminated from upstream reaches in the 1950's, apparently due to some upstream source of toxicity. Between 1963 and 1975, the condition factor of carp declined in the Illinois River as a whole, and the declines were relatively greater in the study reach, so that differences in carp condition in the study area and upstream areas are not as great as formerly. Boat traffic and dredging may affect commercial species of fish and the organisms on which they feed.

13. The mussel fishery in the study area of the Illinois River declined due to pollution and overharvesting prior to completion of the 9-foot navigation system. The increasing sediment input from tributary streams, the dams associated with the 9-foot channel, and the decrease in Lake Michigan Diversion may have affected the mussel fauna by reducing the current velocity and increasing sedimentation in some areas. Dredging operations to maintain the navigation channel can destroy mussel beds. The increase in boat traffic which resulted from construction of the 9-foot channel has probably affected mussels. Barges resuspend bottom sediments and temporarily draw water away from shallow areas as they pass. Large pleasure boats and barges produce wave wash along the shores. All these disturbances can adversely affect mussels in the Illinois River.

14. We were not able to find any information documenting historical changes in mussel populations in the study area of the Mississippi. Navigation dams in other reaches of the upper Mississippi River have slowed the current and facilitated deposition of sediment, with adverse effects on mussels such as yellow sand-shells (*Lampsilis anodontoides*). Movements of fish which serve as mussel hosts may have been impeded by dams. Dredging, deposition of spoil, and boat traffic may have detrimental effects as described above for Illinois fishes.

15. Between 1915 and 1964, the average density of midges in the study reach of the Illinois River increased from 1.3 to 353 per square meter, and the number of oligochaete worms increased from 2.6 to 2,579 per square meter, indicating the presence of soft mud bottoms, an increase in the organic load in the river, and slight decreases in the average dissolved oxygen levels. Snails and fingernail clams also increased between 1915 and 1964, as did leeches, some of which prey on clams and snails. Fingernail clams generally thrive in areas where there is a moderate amount of organic pollution, and where soft mud bottoms are available. Between 1964 and the 1970's, the fingernail clam populations declined slightly (the declines are very slight, and perhaps insignificant), Asiatic clams invaded the river, and the snails either disappeared entirely or were reduced to such low numbers that they did not show up in the recent collections. Asiatic clams probably first entered the Illinois River in 1970-1971. Some toxic agent present in the lower Illinois River may be eliminating the snails. Pesticides may be implicated, since snails exposed to Illinois River water rapidly accumulate dieldrin (within 24 hours).

16. Benthic studies done prior to the construction of the navigation dams on the Mississippi were concerned with areas outside the study reach.

17. Since we were not able to find any surveys of the plankton in the study reach of the Mississippi prior to the mid-1930's, we were not able to compare plankton populations in the Mississippi before and after construction of the navigation dams.

18. Comparison of plankton data on the Illinois River gathered by Kofoid (1903 and 1904) in 1898 with recent data gathered at the same season, under comparable low-flow conditions, shows that: (a) the average number of small diatoms (Bacillariophyta) doubled, (b) the number of large diatoms remained the same, (c) small green algae (Chlorophyta) increased, (d) large green algae declined, (e) blue-green algae

(Cyanophyta) declined markedly by a factor of 80 to 100, (f) rotifers declined by a factor of 10, and (g) copepods increased slightly. The decline in blue-green algae may be attributable to increased suspended solids and turbidity in the Illinois River. The diatoms probably persisted or increased because they can tolerate the reduced light and increased abrasion associated with suspended sediment. Because the diatoms persisted, and because they are at least as sensitive to toxicants as other algae (such as blue-greens), the decline in blue-greens probably is not attributable to toxicity. The change in phytoplankton and the increase in the suspended solids load of the lower Illinois River may have impaired the feeding of rotifers, thereby reducing their populations. Rotifers are an important food for the fry of many game fish, such as bluegill, so the reduction in rotifers might have had a significant impact on the growth and survival of fish fry.

19. Wetland vegetation was inundated when the 9-foot channel project raised water levels and initially created additional water areas. However, new areas were pioneered, resulting in expanded aquatic plant and marsh acreage.

20. Since increases in water levels can destroy wetland vegetation after it has become established in shallow water and on exposed mud flats in the summer, the stabilizing effects of the dams in most years between 1948-1968 on Pool 26 resulted in excellent plant growth. Pool 25 was subject to frequent and sometimes severe fluctuations in 1948-1951, 1954, 1958, 1961, and 1967, which adversely affected wetland vegetation.

21. The greatest adverse effect of the 9-foot channel project on wetland vegetation has resulted from an increase in turbidity and sedimentation. Plants need sunlight for photosynthesis. Turbidity

reduces the clarity of the water, thereby limiting the amount of sunlight reaching submerged and emergent aquatic plants. Turbidity has extirpated the submerged aquatic plants and reduced marsh acreage in the unprotected backwater areas of Pools 24-26.

22. Sedimentation has produced extremely soft bottoms which make it difficult for aquatic and marsh plants to gain or retain a roothold when exposed to wave action. Sedimentation also affects these plants by physically smothering plant beds and partially filling backwater areas, thus reducing water acreage and limiting the diversity of habitats available for plant colonization by creating a uniform bottom.

Although aquatic and marsh plants were adversely affected, sedimentation has filled shallow areas, creating mud flats which at present exceed preproject acreage. The moist soil plants that volunteer on these mud flats were benefited by increased sedimentation.

23. The 9-foot navigation project benefited waterfowl populations by creating many thousands of acres of shallow water. Increased backwaters provided shallow areas which supported both marsh and submerged aquatic plant growth. The mallard has been the principal species of waterfowl benefited by the project. Canada, blue, and snow geese use of the project area also has increased as a result of management of habitat by states, the U.S. Fish and Wildlife Serivce, and private duck clubs, to increase the production of both natural and artificially-seeded food plants. However, as a result of man-made pool level fluctuations during several years in Pools 25 and 26, waterfowl feeding areas were degraded.

24. Increased sedimentation and turbidity have led to the loss of submerged aquatic plants in most of the project area. This loss of plant food has been responsible for declining numbers of wigeon, green-wing teal, and lesser scaup in the project area. In addition, increased

sedimentation has filled shallow areas in the backwaters which once supported marsh plants, destroying habitat. The temporary benefit of sedimentation to waterfowl has been the creating of mud flats which produce moist soil plants when proper water level manipulation occurs.

25. The 9-foot channel project affected bald eagles by initiating an earlier freeze-up on the lower part of the pools, restricting the eagles' feeding area. However, the benefit of open tailwaters in midwinter probably outweighs the early-winter loss of feeding grounds.

26. The initial increase in marsh areas as a result of the 9-foot channel benefited common gallinule, sora, Virginia rail, heron, and egret populations. The subsequent loss of marsh habitat due to sedimentation and the increase in turbidity, restricting sight feeding, has adversely affected these birds.

27. The implementation of the 9-foot channel project inundated existing mud flats used as feeding areas for shorebirds. Increased sedimentation has recreated and produced more mud flats thereby increasing feeding areas for shorebirds. Gulls and terns were benefited by the increased water acreage as a result of the 9-foot channel project.

28. Bottomland timber was cleared in preparation for the 9-foot channel project, thereby destroying habitat for woodcock, snipe, songbirds, and woodpeckers. There was little effect on cormorants, bobwhite quail, ring-necked pheasants, mourning doves, and wild turkeys.

29. The construction of the 9-foot channel project initially benefited muskrats by increasing marsh areas. However, as a result of increased sedimentation and subsequent destruction of aquatic and marsh plants, much of the early benefits have been lost.

30. The inundation of bottomland timber by the 9-foot channel project reduced the habitat for raccoon, striped skunk, red and grey foxes, opossum, white-tailed deer, fox and gray squirrels, and rabbits, but had little effect on beaver and mink.

LITERATURE CITED

Aldrich, A.W. 1886. Sixth biennial report of the State Fish Commission of Iowa, for the years 1883-84 and 1884-85. Legislative Documents Submitted to the 21st General Assembly of Iowa. Volume IV.

Aldrich, S.R. 1965. Illinois field crops and soils. Cooperative Extension Service, College of Agriculture, University of Illinois. Urbana, Illinois.

Anderson, A.W. and C.E. Peterson. 1953. Fishery statistics of the United States, 1950. U.S. Fish and Wildlife Service Statistical Digest 27. 492 p.

Anderson, A.W. and E.A. Power. 1957. Fishery statistics of the United States, 1955. U.S. Fish and Wildlife Service Statistical Digest 41. 446 p.

Anderson, H.G. 1959. Food habits of migratory ducks in Illinois. Illinois Natural History Survey Bulletin 27(4): 289-344.

Anderson, K.B. 1977. Musculium transversum in the Illinois River and an acute potassium bioassay method for the species. M.S. thesis. Western Illinois University. Macomb, Illinois. 79 p.

Anderson, K.B., M.J. Sandusky, and R.E. Sparks. 1977. The toxicity of potassium, undissociated ammonia, and Illinois River water to the fingernail clam, Musculium transversum. Unpublished paper presented at the 39th Midwest Fish and Wildlife Conference, Madison, Wisconsin, 5 December 1977. 13 p.

Astor, R.J. 1973. Tubificids and water quality: a review. Environmental Pollution 5(1): 1-10.

Baker, F.C. 1906. A catalog of the mollusca of Illinois. Illinois State Laboratory of Natural History Bulletin 7(6): 53-136.

Barnickol, P.G. and W.C. Starrett. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri and Dubuque, Iowa. Bulletin of the Illinois Natural History Survey 25(5): 267-350.

Barrows, H.H. 1910. Geography of the middle Illinois valley. Illinois State Geological Survey Bulletin No. 15. 128 p.

Bartlett, S.P. 1900. The value of carp as a food product of Illinois waters. Transactions of the American Fisheries Society 29: 80-86. Non videmus.

Bartow, E. 1913. Chemical and biological survey of the waters of Illinois. University of Illinois Bulletin, Water Survey Series No. 10. 198 p.

Bellrose, F.C. 1941. Duck food plants of the Illinois river valley. Illinois Natural History Survey Bulletin 21(8): 237-280.

Bellrose, F.C. 1943. Proposed management of upper Mississippi navigation pool for wildlife. Unpublished paper.

Bellrose, F.C. 1950. A relationship of muskrat populations to plants. Journal of Wildlife Management 14(3): 299-315.

Bellrose, F.C. 1954. The value of waterfowl refuges in Illinois. Journal of Wildlife Management 18(2): 160-169.

Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Stackpole Books. Harrisburg, Pennsylvania. 540 p.

Bellrose, F.C. and J.B. Low. 1943. The influence of food and low water levels on the survival of muskrats. Journal of Mammalogy 24: 173-188.

Bellrose, F.C., R.E. Sparks, F.L. Paveglio, Jr., D.W. Steffeck, R.C. Thomas, R.A. Weaver, and D. Moll. 1977. Fish and wildlife habitat changes resulting from the construction of a nine-foot navigation channel in the Illinois Waterway from LaGrange Lock and Dam upstream to Lockport Lock and Dam. Department of the Army Chicago District, Corps of Engineers. 176 p.

Bertrand, B. and B. Dunn. 1973. Fish population survey of aquatic habitat types in Pool 25 of the Mississippi River. Illinois Department of Conservation Division of Fisheries. 13 p.

Bertrand, B. and B. Dunn. 1974. Fish population survey of stations in Pools 21, 24, 25, and 26 of the Mississippi River. Illinois Department of Conservation Division of Fisheries. 12 p.

Bertrand, B. and R. Lockart. 1973. Fish population survey of aquatic habitat types in Pool 26 and below 26 in the Alton area of the Mississippi River. Illinois Department of Conservation Division of Fisheries. 14 p.

Brown, L.G. and L.E. Yeager. 1943. Survey of the Illinois fur resource. Bulletin of the Illinois Natural History Survey 22(6): 435-504.

Buswell, A.M. 1927. Pollution of streams in Illinois. Illinois State Water Survey Bulletin No. 24. 35 p.

Butts, T.A. 1975. Lake Meredosia sample results. 14 p. Unpublished.

Butts, T.A., R.L. Evans, and S. Lin. 1975. Water quality features of the Upper Illinois Waterway. Illinois State Water Survey. Urbana. 60 p.

Cahn, A.R. 1949. Pearl culture in Japan. General Headquarters, Supreme Commander for the Allied Powers, Natural Resources Section Report 122. 91 p.

Carlander, H.B. 1954. History of fish and fishing in the upper Mississippi River. Upper Mississippi River Conservation Committee. 96 p.

Chamberlain, E.B., Jr. 1948. Ecological factors influencing the growth and management of certain waterfowl food plants on Back Bay National Wildlife Refuge. Transactions of the North American Wildlife Conference 13: 347-355.

Chicago District, Corps of Engineers. 1975. Preliminary investigation of the downstream effects on the Illinois Waterway of an increase in Lake Michigan diversion at Chicago, Illinois. 49 p.

Christenson, L.M. and L.L. Smith. 1965. Characteristics of fish populations in upper Mississippi River backwater areas. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. Circular 212. 53 p.

Cleary, R.E. 1961. Mississippi fishing from a statistician's viewpoint. Iowa Conservationist 20(6): 143.

Cohen, N.H., S.P. Bartlett, and H. Kleine. 1908. Report of Illinois State Fish Commissioners, from October 1, 1906 to September 30, 1908. 92 p.

Coker, R.E. 1914. Water-power development in relation to fishes and mussels of the Mississippi. U.S. Commercial Fisheries Report for 1913. Bureau of Fisheries Document No. 805. Appendix 8. 28 p.

Coker, R.E. 1921. Fresh-water mussels and mussel industries of the United States. U.S. Bureau of Fisheries Bulletin for 1917-1918, 36: 11-89.

Coker, R.E. 1930. Studies of common fishes of the Mississippi River at Keokuk, 1930. Bureau of Fisheries Document 1072, Bulletin of Bureau of Fisheries 45: 141-225.

Coker, R.E., Shira, Clark, and Howard. 1921. Life history and propagation of fresh-water mussels. Bulletin of U.S. Bureau of Fisheries 36(85): 135-166.

Colbert, B.K., J.E. Scott, J.H. Johnson, and R.C. Solomon. 1975. Environmental inventory and assessment of navigation pools 24, 25, and 26, upper Mississippi and lower Illinois Rivers: an aquatic analysis. U.S. Army Engineers Waterways Experiment Station. Technical Report Y-75-2. 361 p.

Culler, C.F. 1934. The future of the upper Mississippi fisheries. Transactions of the American Fisheries Society 64: 328-331.

Danglade, E. 1914. The mussel resources of the Illinois River. U.S. Bureau of Fisheries, Appendix No. 6 to the Report of the U.S. Commissioner of Fisheries for 1913. 48 p.

Department of Commerce. 1976. Fishery statistics of the United States 1973. Statistical Digest No. 67. U.S. Government Printing Office. Washington, D.C. 458 p.

Department of Commerce and Labor. 1911. Special reports. Fisheries of the United States 1908. Government Printing Office. Washington, D.C. 324 p.

Department of Registration and Education. 1931. Fourteenth annual report, July 1, 1930-June 30, 1931. Springfield, Illinois.

Department of Registration and Education. 1932. Fifteenth annual report, July 1, 1931-June 30, 1932. Springfield, Illinois.

Dorris, T.C. 1958. Limnology of the middle Mississippi River and adjacent waters. Lakes on the leveed floodplain. The American Midland Naturalist 59(1): 82-110.

Dorris, T.C. and B.J. Copeland. 1962. Limnology of the middle Mississippi River III. Mayfly populations in relation to navigation water-level control. Limnology and Oceanography 7(2): 240-247.

Dorris, T.C. and B.J. Copeland. 1963. Limnology of the middle Mississippi River IV. Physical and chemical limnology of river and chute. Limnology and Oceanography 8(1): 79-88.

Dunham, L.L. 1970a. Aerial recreation survey of the Mississippi River. Illinois Department of Conservation, Division of Fisheries. 13 p.

Dunham, L.L. 1970b. Fish sampling by electro-fishing gear below ten navigation dams on the Mississippi River. Illinois Department of Conservation, Division of Fisheries. 9 p.

Dunham, L.L. 1971. Fish sampling by electro-fishing gear below navigation dams No. 12-26 on the Mississippi River. Illinois Department of Conservation, Division of Fisheries. 22 p.

Ellis, M.M. 1931a. A survey of conditions affecting fisheries in the upper Mississippi River. U.S. Department of Commerce, Bureau of Fisheries, Fishery Circular No. 5. 18 p.

Ellis, M.M. 1931b. Some factors affecting the replacement of the commercial fresh-water mussels. U.S. Department of Commerce, Bureau of Fisheries, Fishery Circular No. 7. 10 p.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1): 29-42.

Fiedler, R.H. 1933. Fishery industries of the United States, 1932. Appendix III to Report of Commissioner of Fisheries for Fiscal Year 1933: 149-449.

Fleener, G.G. 1975. The 1972-1973 sport fishery survey of the upper Mississippi River. Upper Mississippi River Conservation Committee. 112 p.

Forbes, S.A. and R.E. Richardson. 1913. Studies on the biology of the upper Illinois River. Illinois State Laboratory of Natural History Bulletin 9(10): 481-574.

Forbes, S.A. and R.E. Richardson. 1919. Some recent changes in Illinois River biology. Illinois State Natural History Survey Bulletin 13(6): 139-156.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Second edition. Illinois Natural History Survey. Urbana, Illinois. 357 p. + atlas.

Gale, W.F. 1969. Bottom fauna of Pool 19, Mississippi River with emphasis on the life history of the fingernail clam, Sphaerium transversum. Ph.D. thesis. Iowa State University of Science and Technology. Ames, Iowa. 234 p.

Galtsoff, P.S. 1924. Limnological observations in the upper Mississippi, 1921. Bulletin of the Bureau of Fisheries, 1923-24, 39: 347-438. Document No. 958.

Garman, H. 1896. A preliminary report on the animals of the Mississippi bottoms near Quincy, Illinois in August, 1888. Part I. Bulletin of the Illinois Natural History Survey 3(9): 123-184.

Gaufin, A.R. 1973. Use of aquatic invertebrates in the assessment of water quality, p. 96-116. In: J. Cairns, Jr. and K.L. Dickson, eds. Biological methods for the assessment of water quality. Special Technical Publication No. 28. American Society for Testing and Materials. Philadelphia, Pennsylvania.

Goodnight, C.J. 1973. The use of aquatic invertebrates as indicators of stream pollution. Transactions of the American Microscopy Society 92(1): 1-13.

Graber, R.R. 1976. Mississippi River heron census IV. Unpublished. Illinois Natural History Survey. Urbana, Illinois.

Gray, A., B.L. Robinson, and M.L. Fernald. 1908. Gray's new manual of botany. Seventh edition. American Book Co. New York. 926 p.

Green, W.E. 1960. Ecological changes on the Upper Mississippi River Fish and Wildlife Refuge since inception of the 9-foot channel. Revised. U.S. Department of Interior, Fish and Wildlife Service. 14 p.

Greenbank, J.T. 1946. Effects of midwinter drawdowns of the upper Mississippi River on aquatic wildlife. In: Keenlyne, K.D., ed. Upper Mississippi River Conservation Committee investigational reports. Upper Mississippi River Conservation Committee. 179 p.

Gunter, G. 1957. Wildlife and flood control in the Mississippi valley. Transactions of the North American Wildlife Conference 22: 189-196.

Helms, D.R. 1969. Habitat use by Mississippi River anglers. Iowa Conservation Commission Quarterly, Biological Reports 21(1): 33-54.

Hoffmeister, D.F. and C.O. Mohr. 1972. Fieldbook of Illinois mammals. Dover Publications, Inc. New York. 233 p.

Hooker, E.H. 1897. The suspension of solids in flowing water. Transactions of American Society of Civil Engineers 36: 239-324.

Hubley, R.C., Jr. 1961. Harvest and movement of channel catfish in the upper Mississippi River. Wisconsin Conservation Department, Fish Management Division. Investigational Memorandum No. 12. 11 p.

Hunt, B.P. 1953. The life history and economic importance of a burrowing mayfly, Hexagenia limbata, in southern Michigan lakes. Michigan Department of Conservation Bulletin, Institute for Fisheries Research 4. 151 p.

Jackson, H.O. and W.C. Starrett. 1959. Turbidity and sedimentation at Lake Chautauqua, Illinois. Journal of Wildlife Management 23(2): 157-168.

Johnson, J.H. 1976. Effects of tow traffic on the resuspension of sediments and on dissolved oxygen concentrations in Illinois and upper Mississippi Rivers under normal pool conditions. U.S. Army Engineer Waterways Experiment Station, Environmental Effects Laboratory. Vicksburg, Mississippi. Technical Report Y-76-1. 181 p.

Jude, D.J. 1968. Bottom fauna utilization and distribution of 10 species of fish in Pool 19, Mississippi River. M.S. thesis. Iowa State University of Science and Technology. Ames, Iowa. 238 p.

Karaki, S., and J. VanHoften. 1974. Resuspension of bed material and wave effects on the Illinois and upper Mississippi Rivers caused by boat traffic. U.S. Army Engineer District, St. Louis. 31 p.

Keenlyne, K.D., ed. 1974. Upper Mississippi River Conservation Committee investigational reports. Upper Mississippi River Conservation Committee. 179 p.

Kelley, D.W. 1949. Suggested effects of the proposed twelve-foot channel on fish life in the upper Mississippi River. In: Keenlyne, K.D., ed. 1974. Upper Mississippi River Conservation Committee investigational reports. Upper Mississippi River Conservation Committee. 179 p.

Klant, R.F. and P.J. Vidal. 1958. The Mississippi River sport fishery survey, 1956 and 1957, Illinois section, Volume II. Final report of the 1956-57 survey. Illinois Department of Conservation, Division of Fisheries. 290 p.

Klein, W.M., R.H. Daley, and J. Wedum. 1975. Environmental inventory and assessment of navigation pools 24, 25, and 26, upper Mississippi and lower Illinois Rivers. A vegetational study. U.S. Army Engineer Waterways Experiment Station, Environmental Effects Laboratory. Vicksburg, Mississippi. Contract Report Y-75-1. 114 p.

Kofoid, C.A. 1903. Plankton studies. IV. The plankton of Illinois River, 1894-1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part I. Quantitative investigation and general results. Illinois Laboratory of Natural History Bulletin 6(2): 95-635.

Kofoid, C.A. 1904. Plankton studies. V. The plankton of the Illinois River, 1894-1899. Part II. Constituent organisms and their seasonal distribution. Illinois Laboratory of Natural History Bulletin 8(1): 1-361.

Kunz, G.F. 1897. The fresh-water pearls and pearl fisheries of the United States. Bulletin of the United States Fish Commission, 1897: 373-426.

Lee, M.T. 1976. Sediment deposition of Lake Chautauqua, Havana, Illinois. Illinois State Water Survey. Urbana, Illinois. 10 p.

Lee, M.T. and J.B. Stall. 1976. Sediment deposition in Lake Depue, Depue, Illinois and its implications for future lake management. Illinois State Water Survey. Urbana, Illinois. 31 p.

Lee, M.T., J.B. Stall, and T.A. Butts. 1976. The 1975 sediment survey of Lake Meredosia. Illinois State Water Survey. Urbana, Illinois. 30 p.

Leopold, A.S. 1939. Notes on the Mississippi River pools and their effect on wildlife. Unpublished. 3 p.

Lopinot, A.C. 1967. The Illinois mussel. Outdoor Illinois 6(3): 8-15.

Lopinot, A.C. 1968. Illinois fresh-water mussel shell industry. Illinois Department of Conservation Special Fisheries Report No. 24. 23 p.

Low, J.B. and F.C. Bellrose. 1944. The seed and vegetative yield of waterfowl food plants in the Illinois River valley. Journal of Wildlife Management 8(1): 7-22.

Lyles, C.H. 1967. Fishery statistics of the United States, 1965. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries. Statistical Digest 59. 756 p.

McKee, S.E. and H.W. Wolf. 1963. Water quality criteria. State Water Quality Control Board Publication No. 3-A. The Resources Agency of California. Sacramento, California. 548 p.

Martin, A.C. and F.M. Uhler. 1939. Food of game ducks in the United States and Canada. U.S. Department of Agriculture Technical Bulletin No. 634. 156 p.

Mills, H.B., W.C. Starrett, and F.C. Bellrose. 1966. Man's effect on the fish and wildlife of the Illinois River. Illinois Natural History Survey Biological Notes No. 57. Urbana, Illinois. 24 p.

Mohr, C.O. 1943. Illinois furbearers. Bulletin of the Illinois Natural History Survey 22(7): 505-537.

Newspaper Enterprise Association. 1977. The world almanac and book of facts. New York. 976 p.

Nord, R.C. 1964. The 1962-1963 sport fishery survey of the upper Mississippi River. Upper Mississippi River Conservation Committee. 209 p.

Nord, R.C., ed. 1967. A compendium of fishery information on the upper Mississippi River. Upper Mississippi River Conservation Committee. 238 p.

Paloumpis, A.A. and W.C. Starrett. 1960. An ecological study of the benthic organisms in three Illinois River floodplain lakes. The American Midland Naturalist 64(2): 406-435.

Parmalee, P.W. 1967. The fresh-water mussels of Illinois. Illinois State Museum, Popular Science Series, Vol. 8. Springfield, Illinois. 108 p.

Patrick, R. and C.W. Reimer. 1966. The diatoms of the United States. Volume I. Philadelphia Academy of Natural Sciences. Monograph No. 13. Philadelphia, Pennsylvania.

Perry, E. 1978 (in press). A survey of upper Mississippi River mussels. In: Rasmussen, J.L., ed. A compendium of fishery information on the upper Mississippi River. Second edition. Upper Mississippi River Conservation Committee Special Publication.

Platner, W.S. 1946. Water quality studies of the Mississippi River. U.S. Fish and Wildlife Service, Special Scientific Report 30. 77 p.

Power, E.A. 1962. Fishery statistics of the United States, 1960. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries. Statistical Digest 53. 529 p.

Praeger, W.E. 1925. Birds of the Des Moines rapids. The Auk 42(4): 563-577.

Richardson, R.E. 1921a. Changes in the bottom fauna and shore fauna of the middle Illinois River and its connecting lakes since 1913-1915 as a result of the increase, southward, of sewage pollution. Illinois State Natural History Survey Bulletin 14(4): 33-75.

Richardson, R.E. 1921b. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton: its valuation; its sources of food supply; and its relation to the fishery. Illinois State Natural History Survey Bulletin 13(15): 363-522.

Richardson, R.E. 1925. Illinois River bottom fauna in 1923. Illinois State Natural History Survey Bulletin 15(6): 391-422.

Richardson, R.E. 1928. The bottom fauna of the middle Illinois River, 1913-1925. Illinois Natural History Survey Bulletin 17(12): 387-475.

Robbins, C.S., B. Braun, H.S. Zim, and A. Singer. 1966. A guide to field identification: birds of North America. Western Publishing Co., Inc. Racine, Wisconsin. 340 p.

Robel, K.J. 1961. Water depth and turbidity in relation to growth of sago pondweed. Journal of Wildlife Management 25(4): 436-438.

Robinson, J.W. 1970. The 1969 upper Mississippi River dredge spoil survey, from Hastings, Minnesota to Cairo, Illinois. Upper Mississippi River Conservation Committee, Fish Technical Section. 155 p.

Rubey, W.W. 1952. Geology and mineral resources of the Hardin and Brussels quadrangles. U.S. Geological Survey Professional Paper 218. Non videmus.

Sanderson, G.C. 1977. Management of migratory shore and upland game birds in North America. The International Association of Fish and Wildlife Agencies, in cooperation with the U.S. Department of Interior, Fish and Wildlife Service. 358 p.

Saxon, L. 1927. Father Mississippi. Century Co. New York. 427 p.

Sette, O.E. 1925. Fisheries industries of the United States, 1923. Appendix IV, Report U.S. Commissioner of Fisheres for 1924 (1925). Bureau of Fisheries Document 976. 219 p.

Simons, D.B., S.A. Schumm, M.A. Stevens, Y.H. Chen, and P.F. Lagasse. 1975. Environmental inventory and assessment of navigation pools 24, 25, and 26, upper Mississippi and lower Illinois Rivers. A geomorphic study. U.S. Army Engineer Waterways Experiment Station, Environmental Effects Laboratory. Vicksburg, Mississippi. Contract Report Y-75-4. 488 p.

Smith, F. 1911. Double-crested cormorants breeding in central Illinois. The Auk 28(1): 16-19.

Smith, H.M. 1898. Statistics of the fisheries of the interior waters of the United States. Report of the Commissioner for 1896. U.S. Commission of Fish and Fisheries Part 22: 489-574.

Smith, H.M. 1899. The mussel fishery and pearl-button industry of the Mississippi River. U.S. Fish Commission Bulletin 1898, 18: 289-314.

Smith, L.L. 1946. Second progress report of the technical committee for fisheries. In: Proceedings of the second annual meeting of the Upper Mississippi River Conservation Committee. 83 p.

Smith, P.W. 1971. Illinois streams: a classification based on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Natural History Survey Biological Notes No. 76. Urbana, Illinois. 14 p.

Smith, P.W., A.C. Lopinot, and W.L. Pflieger. 1971. A distributional atlas of upper Mississippi River fishes. Illinois Natural History Survey Biological Notes No. 73. Urbana, Illinois. 20 p.

Solomon, R.C., D.R. Parsons, D.A. Wright, B.K. Colbert, C. Ferris, and J.E. Scott. 1975. Environmental inventory and assessment of navigation pools 24, 25, and 26, upper Mississippi and lower Illinois Rivers. Summary report. U.S. Army Engineer Waterways Experiment Station, Environmental Effects Laboratory. Vicksburg, Mississippi. Technical Report Y-75-1. 97 p.

Sparks, R.E. 1975a. Possible biological impacts of wave wash and resuspension of sediments caused by boat traffic in the Illinois River. Prepared for U.S. Army Corps of Engineers, St. Louis District. St. Louis, Missouri. 23 p.

Sparks, R.E. 1975b. Environmental inventory and assessment of navigation pools 24, 25, and 26, upper Mississippi and lower Illinois Rivers. An electrofishing survey of the Illinois River. Contract Report Y-75-4. U.S. Army Engineer Waterways Experiment Station. Environmental Effects Laboratory. Vicksburg, Mississippi. 123 p.

Sparks, R.E. 1975c. An electrofishing survey of the Illinois River, 1959-1974. Illinois Natural History Survey Bulletin 31(8): 317-380.

Starrett, W.C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. Illinois Natural History Survey Bulletin 30(5): 267-403.

Starrett, W.C. 1972. Man and the Illinois River, p. 131-169. In: R.T. Oglesby, C.A. Carlson, and J.A. McCann, eds. River ecology and the impact of man. Held at the University of Massachusetts, Amherst, Massachusetts, June 20-23, 1971. Academic Press. New York.

Steele, R. 1946. Problems concerning waterfowl and furbearers. Proceedings of the annual meeting, Upper Mississippi River Conservation Committee 2: 16-22.

Stewart, C.L. 1931. Land utilization in the Illinois River basin. Illinois State Water Survey Circular No. 12: 34-40.

Sullivan, J.K. 1971. The development and current status of the upper Mississippi River commercial fishery. Ph.D. thesis. University of Michigan. 168 p.

Taylor, H.F. 1951. Survey of marine fisheries of North Carolina. University of North Carolina Press. Chapel Hill, North Carolina. xii+555 p.

Thompson, C.M. and R.E. Sparks. 1977a. The Asiatic clam, *Corbicula manilensis*, in the Illinois River. The Nautilus 91(1): 34-36.

Thompson, C.M. and R.E. Sparks. 1977b. Status of the fingernail clam, *Musculium transversum*, in the Keokuk Pool, Mississippi River. Unpublished paper presented at the 39th Midwest Fish and Wildlife Conference, Madison, Wisconsin, 5 December 1977.

Thompson, C.M. and R.E. Sparks. 1978. Comparative nutritional value of a native fingernail clam and the introduced Asiatic clam. Journal of Wildlife Management 42(2): 391-396.

Thompson, J.D. 1969. Feeding behavior of diving ducks on Keokuk Pool, Mississippi River. M.S. thesis. Iowa State University of Science and Technology. Ames, Iowa. 79 p.

Townsend, C.H. 1902. Statistics of the fisheries of the Mississippi River and tributaries. Report U.S. Commission of Fish and Fisheries for 1901 (1902): 659-740.

Townsend, C. 1915. The flow of sediment in the Mississippi River and its influence on the slope and discharge. With special reference to the effects of spillways in the vicinity of New Orleans, Louisiana. Professional Memoirs, Corps of Engineers, U.S. Army and Engineer Department at Large 7(33): 357-377.

Trautman, M.B. 1957. The fishes of Ohio. The Ohio State University Press. 683 p.

U.S. Army Engineer District, Chicago, Corps of Engineers. 1974. Charts of the Illinois Waterway from Mississippi River at Grafton, Illinois to Lake Michigan at Chicago and Calumet Harbors. Chicago, Illinois. 77 charts.

U.S. Army Engineer District, St. Louis. 1975. Draft environmental statement. Operation and maintenance, Pools 24, 25, and 26, Mississippi and Illinois Rivers. St. Louis, Missouri. 222 p. + appendices.

U.S. Army Engineer Division, North Central, Corps of Engineers. 1975. Upper Mississippi River navigation charts. Chicago, Illinois. 161 charts.

U.S. Department of Commerce Bureau of the Census. 1975. Historical statistics of the United States -- colonial times to 1970. Bicentennial Edition. Part I.

WAPORA, Inc. 1974. Illinois River ecology as affected by thermal discharges from power plants. 82 p. + appendices A-H in a separate volume.

Weinhold, G.A., R.E. Greenfield, and A.M. Buswell. 1925. A preliminary notice of a survey of the sources of pollution of the streams of Illinois. Illinois State Water Survey Bulletin 20: 34-59.

Wheeland, H.A. 1973. Fishery statistics of the United States, 1970. U.S. Department of Commerce, National Marine Fisheries Service. Statistical Digest 64. 489 p.

Wiebe, A.H. 1927. Biological survey of the upper Mississippi River with special reference to pollution. U.S. Bureau of Fisheries Bulletin 43: 137-166.

Williams, L.G. 1964. Possible relationships between plankton-diatom species numbers and water-quality estimates. Ecology 45(4): 809-823.

Wong, P.T.S., Y.K. Chau, and P.L. Luxon. 1978. Toxicity of a mixture of metals on freshwater algae. Journal of the Fisheries Research Board of Canada 35: 479-481.

Wright, K.J. 1970. The 1967-1698 sport fishery survey of the upper Mississippi River. Upper Mississippi River Conservation Committee. 116 p.

Yeager, L.E. 1949. Effect of permanent flooding in a river-bottom timber area. Bulletin of the Illinois Natural History Survey 25(2): 33-65.

Yeager, L.E. and R.G. Rennels. 1943. Fur yield and autumn foods of the raccoon in Illinois River bottomlands. Journal of Wildlife Management 7(1): 45-60.

APPENDIX

Table 56

List of Common and Scientific Names

Common Name	Scientific Name
PLANTS	
American lotus	*Nelumbo lutea*
Arrowhead	*Lophotocarpus calycinus*
Black willow	*Salix nigra*
Bushy pondweed (Naiad)	*Najas guadalupensis*
Cattail	*Typha latifolia*
Coontail	*Ceratophyllum demersum*
Cron	*Zea mays*
Cottonwood	*Populus deltoides*
Duck potato	*Sagittaria latifolia*
Elm	*Ulmus* spp.
Leafy pondweed	*Potamogeton foliosus*
Long-leaf pondweed	*Potamogeton nodosus*
Maples	*Acer* spp.
Marsh mallow	*Hibiscus militaris*
Marsh smartweed	*Polygonum coccineum*
Nutgrasses	*Cyperus* spp.
Rice cutgrass	*Leersia oryzoides*
River bulrush	*Scirpus fluviatilis*
Sago pondweed	*Potamogeton pecinatus*
Sedges	*Scirpus* spp.
Silver (soft) maple	*Acer saccharinum*
Softstem bulrush	*Scirpus validus*
Spike rush	*Eleocharis palustris*
Smartweeds	*Polygonum* spp.
White water lily	*Nymphaea tuberosa*
Wild millet	*Echinochloa muricata*
BIRDS	
American avocet	*Recurvirostra americana*
American bittern	*Botaurus lentiginosus*
American golden plover	*Pluvialis dominica*
American redstart	*Setophaga ruticilla*
American woodcock	*Philohela minor*
Bald eagle	*Haliaeetus leucocephalus*

Sheet 1 of 8

Table 56 (continued)

Common Name	Scientific Name
	Birds continued
Bewick's wren	Thryomanes bewickii
Black-bellied plover	Squatarola squatarola
Black-capped chickadee	Parus atricapillus
Black-crowned night heron	Nycticorax nycticorax
Black tern	Chilidonias niger
Blue goose	Anser caerulescens
Bobwhite quail	Colinus virginianus
Buff-breasted snadpiper	Tryngites subruficollis
Canada goose	Branta canadensis
Canvasback	Aythya valisineria
Carolina wren	Thryothorus ludovicianus
Caspian tern	Hydroprogne caspia
Cattle egret	Bubulcus ibis
Common egret	Casmerodius albus
Common gallinule	Gallinula chloropus
Common snipe	Capella gallinago
Common tern	Sterna hirundo
Double-crested cormorant	Phalacroxorax auritus
Downy woodpecker	Dendrocopos pubescens
Dunlin	Erolia alpina
Forster's tern	Sterna forsteri
Franklin's gull	Larus pipixcan
Great blue heron	Ardea herodias
Great-crested flychatcher	Myiarchus crinitus
Greater yellowlegs	Totanus melanoleucus
Green heron	Butorides virescens
Green-wing teal	Anas crecca carolinensis
Gulls	Larus spp.
Hairy woodpecker	Dendrocopos villosus
Herring gull	Larus argentatus
House wren	Troglodytes aedon
Killdeer	Charadrius vociferus
Least bittern	Ixobrychus exilis
Least sandpiper	Evolia minutilla
Lesser scaup	Aythya affinis
Lesser yellowlegs	Totanus flavipes
Long-billed dowitcher	Limnodromus scolopaceus
Mallard	Anas platyrhynchos
Mourning dove	Zenaidura macroura
Pectoral sandpiper	Erolia melanotos
Pileated woodpecker	Dryocopus pileatus
Pintail	Anas acuta
Prothonotary warbler	Protonotaria citrea

Sheet 2 of 8

Table 56 (continued)

Common Name	Scientific Name
	Birds continued
Red-bellied woodpecker	Centurus carolinus
Red-eyed vireo	Vireo olivaceus
Red-headed woodpecker	Melanerpes erythrocephalus
Ring-necked pheasant	Phasianus colchicus
Sanderling	Crocethia alba
Semipalmated plover	Charadrius semipalmatus
Semipalmated sandpiper	Ereunetes pusillus
Short-billed dowitcher	Limnodromus grisebus
Snow goose	Anser caerulescens
Solitary sandpiper	Tringa solitaria
Sora rail	Porzana carolina
Spotted sandpiper	Actitis macularia
Stilt sandpiper	Micropalama himantopus
Tree swallow	Irodoprocne bicolor
Tufted titmouse	Parus bicolor
Virginia rail	Rallus limicola
Warbling vireo	Vireo gilvus
Western sandpiper	Ereunetes mauri
White-breasted nuthatch	Sitta carolinensis
Wigeon	Anas americana
Wild turkey	Meleagris gallopavo
Willet	Catoptrophorus semipalmatus
Wilson's phalarope	Steganopus tricolor
Wood duck	Aix sponsa
Wood pewee	Contopus virens
Wood thrush	Hylocichla mustelina
Yellow-shafted flicker	Colaptes auratus
Yellow-throat	Geothlypis trichas
	MAMMALS
Badger	Taxidea taxus
Beaver	Castor canadensis
Bobcat	Lynx rufus
Cottontail rabbit	Sylvilagus floridanus
Coyote	Canis latrans
Fox squirrel	Sciurus niger
Grey fox	Urocyon cinereoargenteus
Grey squirrel	Sciurus carolinensis
Mink	Mustela vison
Muskrat	Ondatra zibethicus
Opossum	Didelphis marsupialis

Sheet 3 of 8

Table 56 (continued)

Common Name	Scientific Name
	Mammals continued
Raccoon	*Procyon lotor*
Red fox	*Vulpes vulpes*
Spotted skunk	*Spilogale putorius*
Striped skunk	*Mephitis mephitis*
Weasel	*Mustela* sp.
White-tailed deer	*Dama virginianus*
	FISH
Alligator gar	*Lepisosteus spatula*
American eel	*Anguilla rostrata*
Banded darter	*Etheostoma zonale*
Banded killifish	*Fundulus diaphanus menona*
Banded sculpin	*Cottus carolinae*
Bantam sunfish	*Lepomis symmetricus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Bigmouth shiner	*Notropis dorsalis*
Black buffalo	*Ictiobus niger*
Black bullhead	*Ictalurus melas*
Black crappie	*Pomoxis nigromaculatus*
Blackchin shiner	*Notropis heterodon*
Blacknose dace	*Rhinichthys atratulus*
Blacknose shiner	*Notropis heterolepis*
Blackside darter	*Percina maculata*
Blackstripe topminnow	*Fundulus rotatus*
Blue catfish	*Ictalurus furcatus*
Blue sucker	*Cycleptus elongatus*
Bluebreast darter	*Etheostoma camurum*
Bluegill	*Lepomis macrochirus*
Bluntnose darter	*Etheostoma chlorosomum*
Bluntnose minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brook silverside	*Labidesthes sicculus*
Brook stickleback	*Culaea inconstans*
Brown bullhead	*Ictalurus nebulosus*
Bullhead minnow	*Pimephales vigilax*
Burbot	*Lota lota*
Carp	*Cyprinus carpio*
Channel catfish	*Ictalurus punctatus*
Chestnut lamprey	*Ichthyomyzon castaneus*
Common shiner	*Notropis cornutus*
Creek chub	*Semotilus altromaculatus*
Crystal darter	*Ammocrypta asprella*

Sheet 4 of 8

Table 56 (continued)

Common Name	Scientific Name
	Fish continued
Pumpkinseed	Lepomis gibbosus
Quillback carpsucker	Carpiodes cyprinus
Rainbow darter	Etheostoma caeruleum
Rainbow trout	Salmo gairdneri
Red shiner	Notropis lutrensis
Redear sunfish	Lepomis microlophus
Redfin shiner	Notropis umbratilis
River carpsucker	Carpiodes carpio
River darter	Percina shumardi
River redhorse	Moxostoma carinatum
River shiner	Notropis blennius
Rock bass	Ambloplites rupestris
Rosyface shiner	Notropis rubellus
Sand shiner	Notropis stramineus
Sauger	Stizostedion canadense
Shorthead redhorse	Moxostoma macrolepidotum
Shortnose gar	Lepisosteus platostomus
Shovelnose sturgeon	Scaphirhynchus platorhynchus
Silver chub	Hybopsis storeiana
Silver lamprey	Ichthyomyzon unicuspis
Silver redhorse	Moxostoma anisurum
Silverband shiner	Notropis shumardi
Silverjaw minnow	Ericymba buccata
Silvery minnow	Hybognathus nuchalis
Skipjack herring	Alosa chrysochloris
Slenderhead darter	Percina phoxocephala
Smallmouth bass	Micropterus dolomieui
Smallmouth buffalo	Ictiobus bubalus
Southern redbelly dace	Phoxinus erythrogaster
Speckled chub	Hybopsis aestivalis
Spotfin shiner	Notropis spilopterus
Spottail shiner	Notropis hudsonius
Spotted sucker	Minytrema melanops
Starhead topminnow	Fundulus notti
Steelcolor shiner	Notropis whipplei
Stonecat	Noturus flavus
Stoneroller	Campostoma anomalum
Striped shiner	Notropis chrysocephalus
Suckermouth minnow	Phenacobius mirabilis
Tadpole madtom	Noturus gyrinus
Trout perch	Percopsis omiscomaycus
Walleye	Stizostedion vitreum
Warmouth	Lepomis gulosus

Sheet 5 of 8

Table 56 (continued)

Common Name	Scientific Name
	Fish continued
Duskystripe shiner	Notropis pilsbryi
Emerald shiner	Notropis atherinoides
Fantail darter	Etheostoma flabellare
Fathead minnow	Pimephales promelas
Flathead catfish	Pylodictis olivaris
Flier	Centrarchus macropterus
Freckled madtom	Noturus nocturnus
Freshwater drum	Aplodinotus grunniens
Ghost shiner	Notropis buchanani
Gizzard shad	Dorosoma cepedianum
Golden redhorse	Moxostoma erythrurum
Golden shiner	Notemigonus chysoleucas
Goldeye	Hiodon alosoides
Grass pickerel	Esox americanus
Green sunfish	Lepomis cyanellus
Highfin carpsucker	Carpiodes velifer
Hornyhead chub	Nicomis biguttatus
Iowa darter	Etheostoma exile
Johnny darter	Etheostoma nigrum
Lake chubsucker	Erimyzon sucetta
Lake sturgeon	Acipenser fulvescens
Largemouth bass	Micropterus salmoides
Least darter	Etheostoma microperca
Logperch	Percina carprodes
Longear sunfish	Lepomis megalotis
Longnose gar	Lepisosteus osseus
Mimic shiner	Notropis volucellus
Mooneye	Hiodon tergisus
Mosquitofish	Gambusia affinis
Mud darter	Etheostoma asprigene
Mudminnow	Umbra limi
Muskellunge	Esox masquinongy
Northern hog sucker	Hypentelium nigricans
Northern pike	Esox lucius
Orangespotted sunfish	Lepomis humilis
Orangethroat darter	Etheostoma spectabile
Ozark minnow	Dionda nubila
Paddlefish	Polyodon spathula
Pallid shiner	Notropis amnis
Pallid sturgeon	Scaphirhynchus albus
Pirate perch	Aphredoderus sayanus
Pugnose minnow	Notropis emiliae
Pugnose shiner	Notropis anogenus

Sheet 6 of 8

Table 56 (continued)

Common Name	Scientific Name
	Fish continued
Weed shiner	*Notropis texanus*
Western sand darter	*Ammocrypta clara*
White bass	*Morone chrysops*
White catfish	*Ictalurus catus*
White crappie	*Pomoxis annularis*
White sucker	*Catastomus commersoni*
Yellow bass	*Morone mississippiensis*
Yellow bullhead	*Ictalurus natalis*
Yellow perch	*Perca flavescens*
	ZOOPLANKTON
Copepods	Copepoda
Crustaceans	Crustacea
Rotifers	Rotifera
Water fleas	Cladocera
	ALGAE
Blue-green algae	Cyanophyta
Desmids, dinoflagellates	Pyrrophyta
Diatoms	Bacillariophyta
Euglenoid algae	Euglenophyta
Green algae	Chlorophyta
Yellow-brown algae	Chrysophyta
	BOTTOM FAUNA
Asiatic clam	*Corbicula manilensis*
Asiatic clams	Corbiculidae
Beetles	Coleoptera
Burrowing mayfly	Hexagenia and Pentagenia; *Hexagenia bilineata*; *Hexagenia rigida*
Caddisflies	Order Trichoptera
Clams	Pelecypoda
Dobson flies	Neuroptera
Dragonflies	Odonata
Fingernail clam	*Musculium transversum* = *Sphaerium transversum*
Fingernail clams	Sphaeriidae
Flatworms	Turbellaria
Flies	Diptera
Leeches	Hirudinea
Maple leaf	*Quadrula quadrula*

Sheet 7 of 8

Table 56 (concluded)

Common Name	Scientific Name
	Bottom Fauna continued
Mayflies	Order Ephemeroptera
Midges	Family Chironomidae
Monkey-face	*Quadrula metanevra*
Mussels	Unionidae
Oligochaete worms	Oligochaeta
Planaria	Tricladida
Pond snail	*Physa*
Snails	Order Gastropoda
Snail	*Lioplax subcarinatus*
Snail	*Valvata tricarinata*
Three-horned warty-back	*Obliquaria reflexa*
Three-ridge	*Amblema plicata*
Tubificid worms	Tubificidae
Washboard	*Megalonaias gigantea*
Yellow sand-shell	*Lampsilis anodontoides*

Sheet 8 of 8

ATE
LMED
7-8